Rosetta - ESA's comet lander mission

Conference or Workshop Item

Rosetta

ESA's Comet Lander Mission

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3 May 2012 Keck Institute for Space Studies Pasadena

Rosetta mission

1993	ESA approve Rosetta mission as a cornerstone mission for its long term science programme. Target comet 46P Wirtanen.
2002	Jan 2003 launch postponed
2003	Feb 2004 launch planned. New target 67P Churyumov-Gerasimenko
2004	March 2nd Launch

Objectives:

Rendezvous with a comet and study the nucleus for more than one year as it passes through perihelion.
Investigate the origin of comets, the relationship between cometary and interstellar material and its implication with regard to the origin of the solar system

67P/Churyumov-Gerasimenko

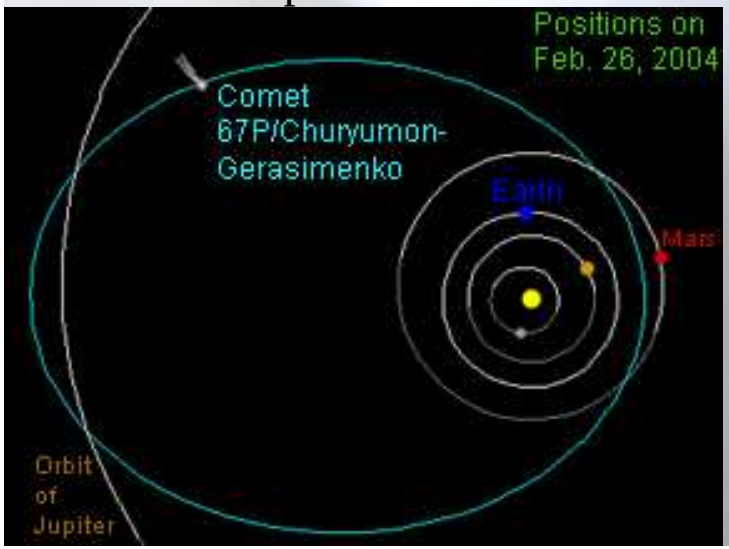
Discovered September 1969 by Klim Churyumov and Svetana Gerasimenko

Perihelion	1.28 AU
Aphelion	5.74 AU
Orbital Period	6.57 years

Most recent perihelion,
2008 magnitude 12

Chosen as new Rosetta target, March 2003

Estimated size of nucleus 3 x 5 km
Rotation period ~12 hours

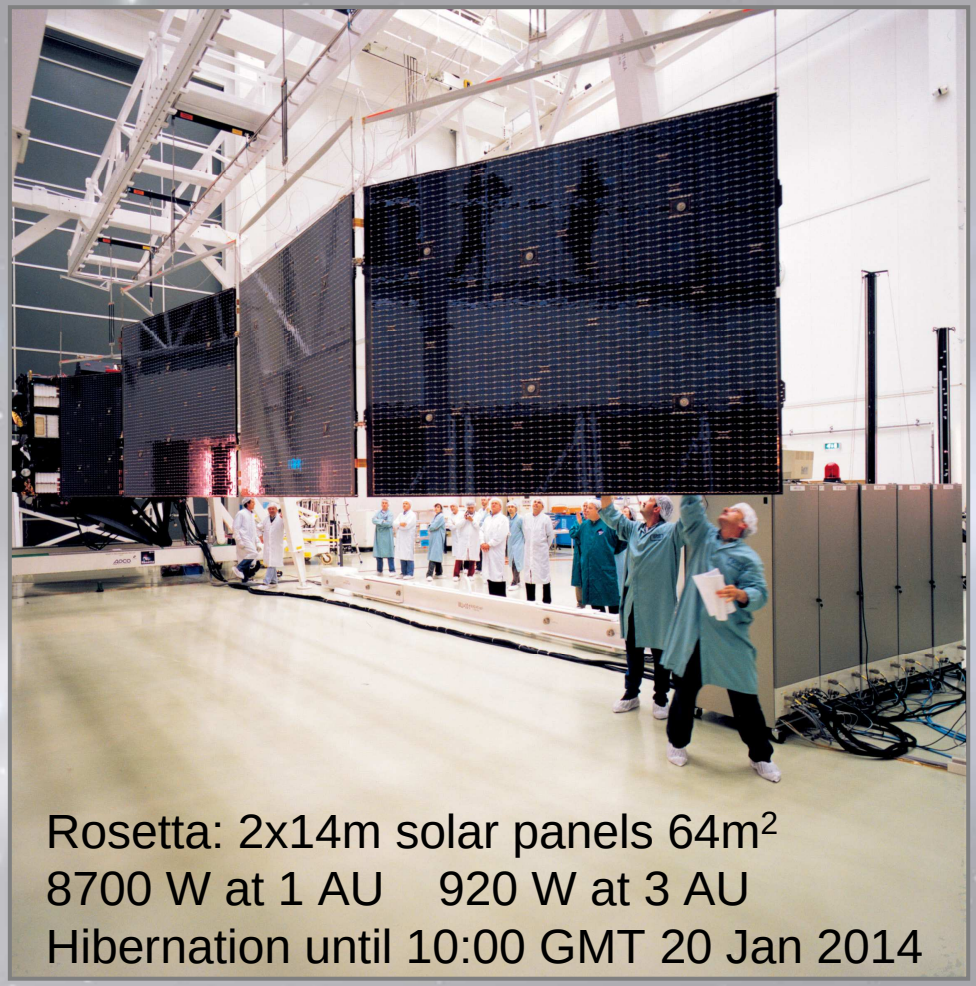


Gas production rate 220kg s^{-1}

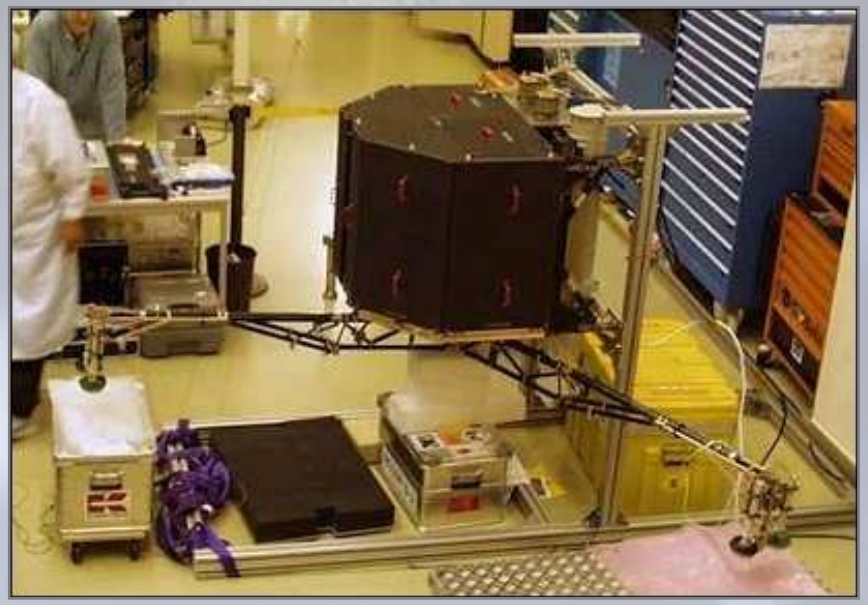
History:

Before 1840, Perihelion	4.0 AU
1840	Close encounter with Jupiter, perihelion 3.0 AU
1959	Close encounter with Jupiter, perihelion 1.29 AU
2007	Encounter with Jupiter, perihelion 1.25AU

Rosetta Power

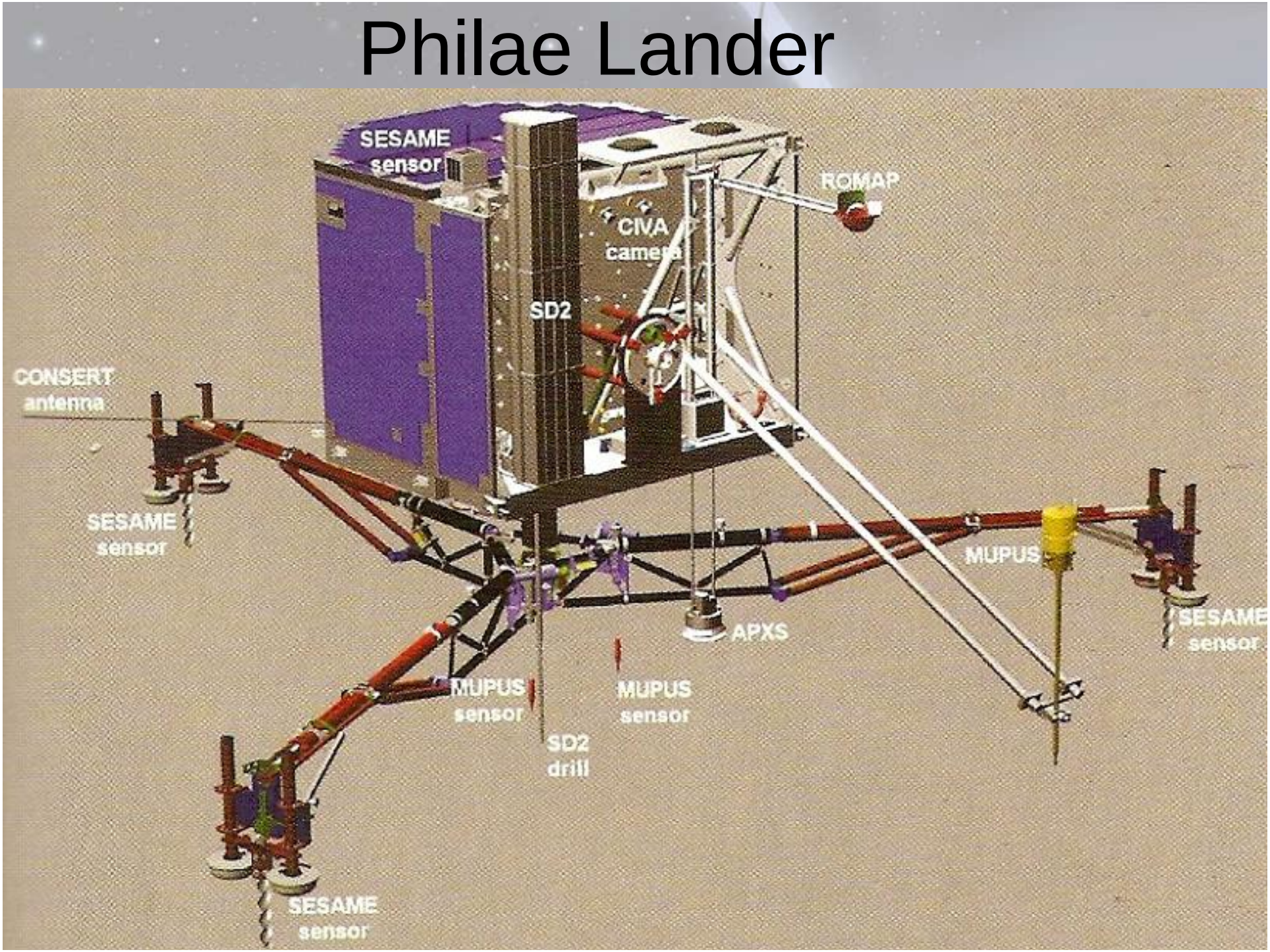


Rosetta: 2x14m solar panels 64m^2
8700 W at 1 AU 920 W at 3 AU
Hibernation until 10:00 GMT 20 Jan 2014



Philae: Solar panels 10 W
Primary batteries 1000 Wh
Secondary batteries 100 Wh

Philae Lander

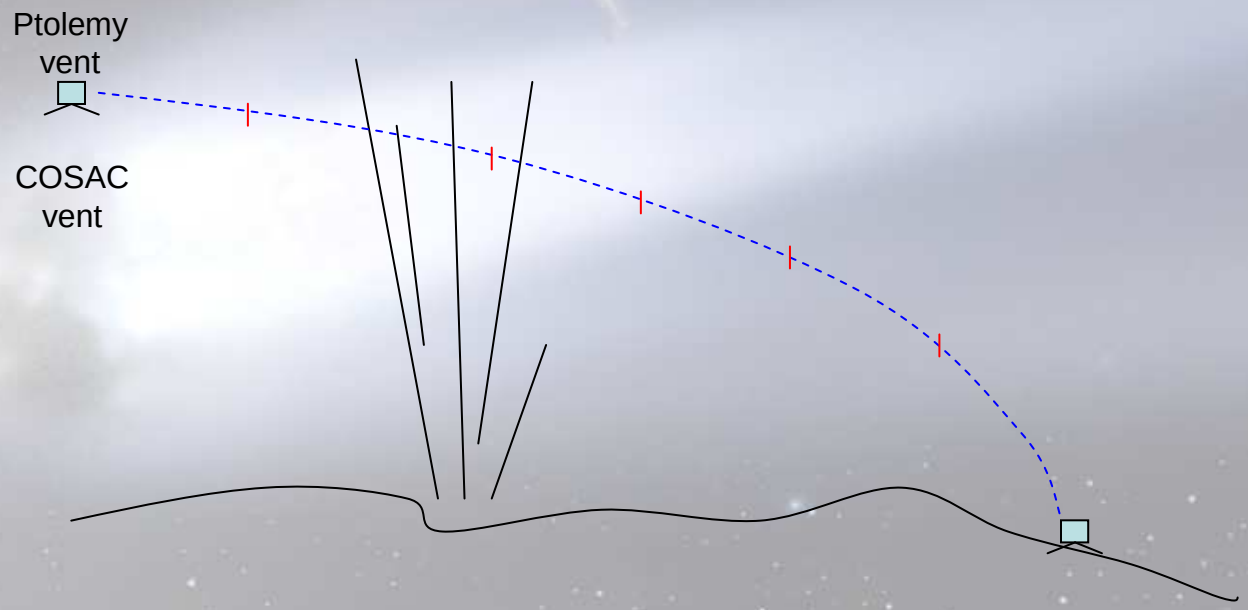


Separation Descent & Landing

Distance 2.7 AU
Height 2 km
Duration 30 min

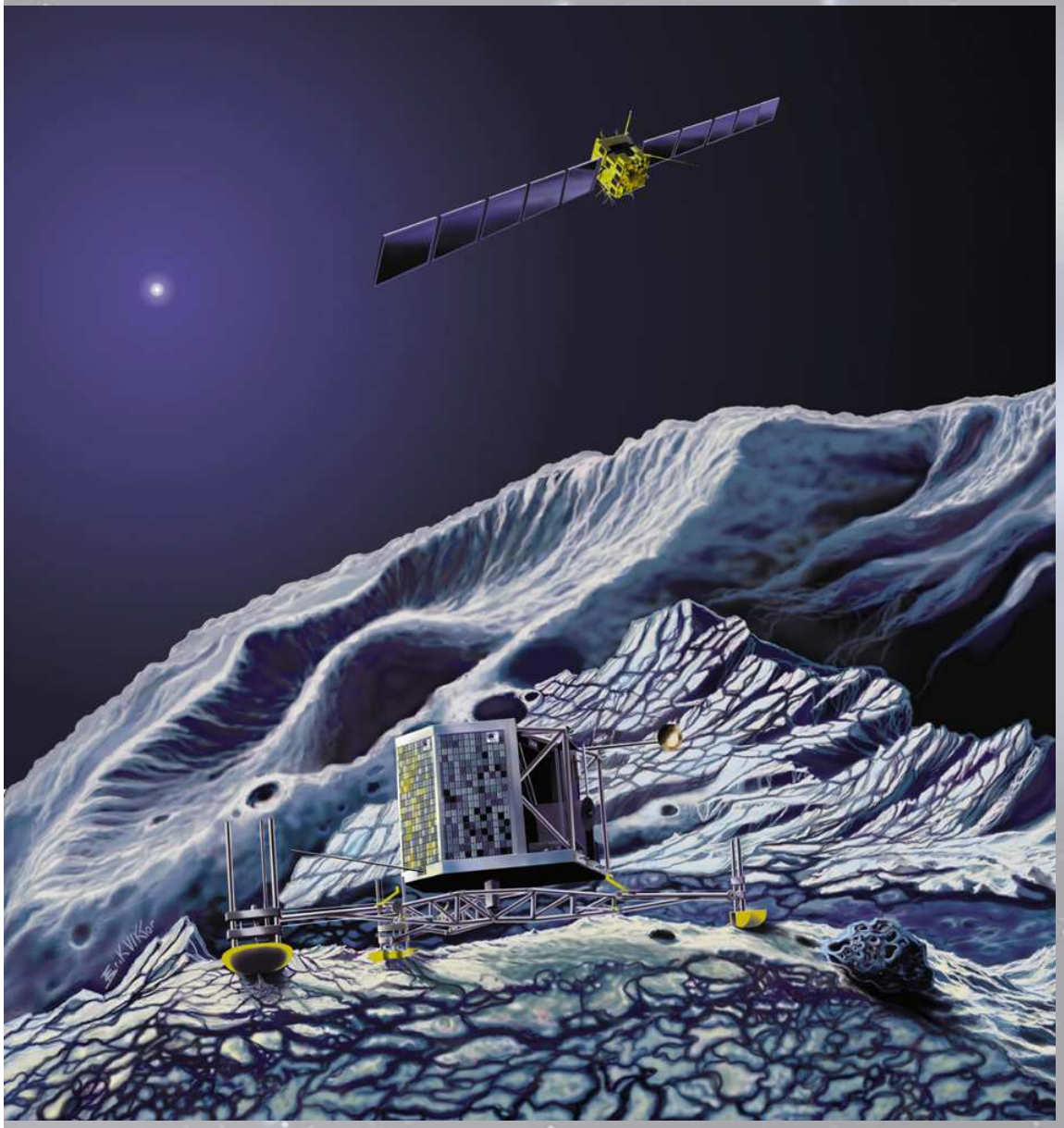
•Try and get measurement if Lander is passing over an interesting area

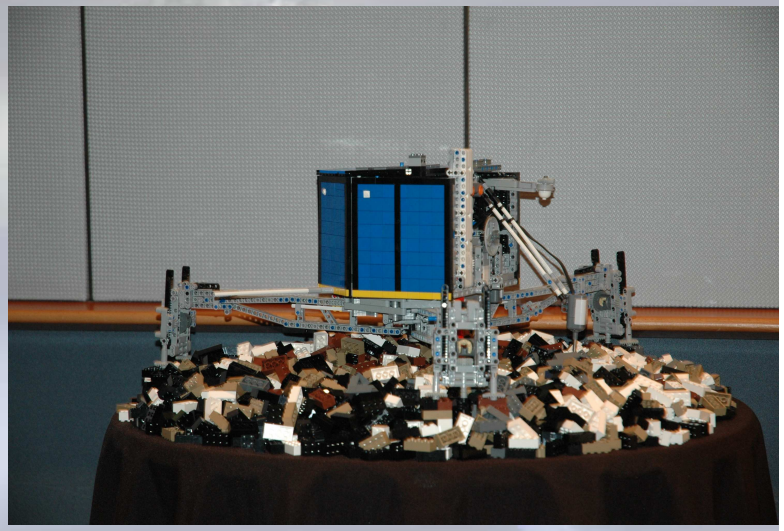
•Mean free path at 10^{-7} mBar ~100m
•Ion molecule reactions



Comet activity at 3.5AU (ICES model) $6x10^{24} – 6x10^{26} – 6x10^{28}$ s^{-1}
Composition 90% H_2O, 9% CO_2, 1% organics
Partial pressure H_2O 1 km from surface ~ $10^{-9} – 10^{-7} – 10^{-5}$ mbar

Rosetta Lander on the comet





Weight on comet ~10 g

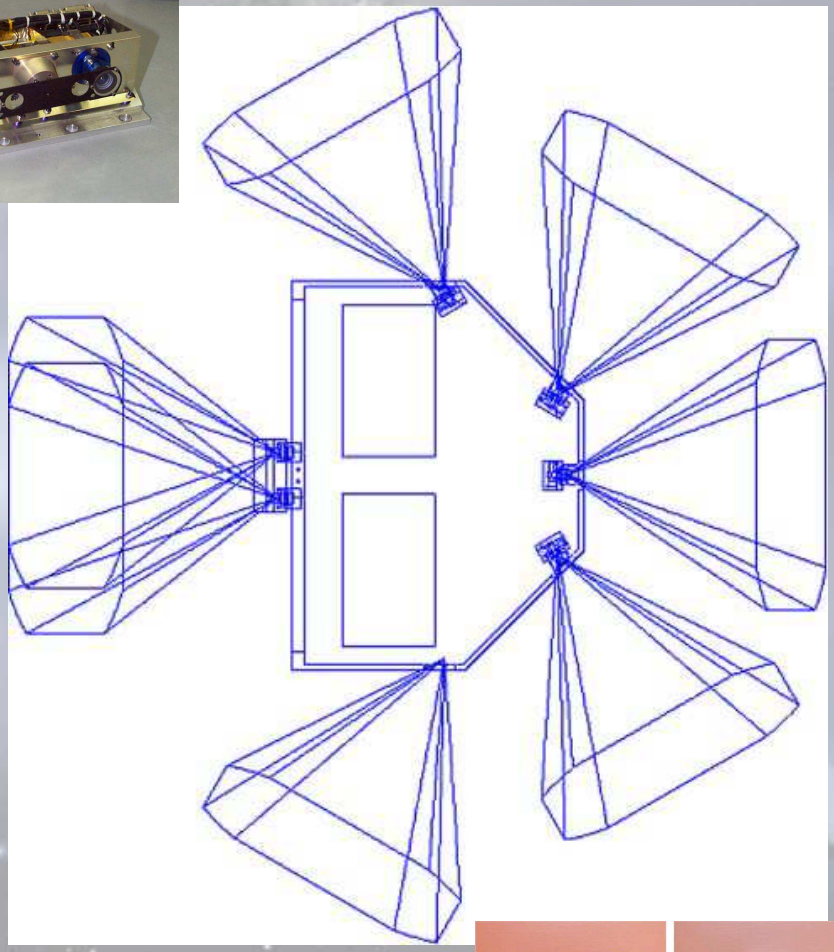
Attached by harpoon & ice screws

Lander Payload….

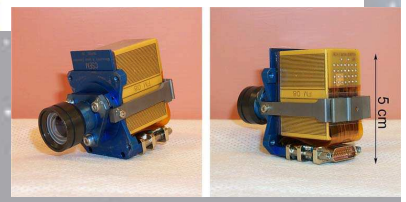
- 11 Instruments
- Rosetta Bible

CIVA Comet Infrared and Visible Analyser

Panoramic Cameras

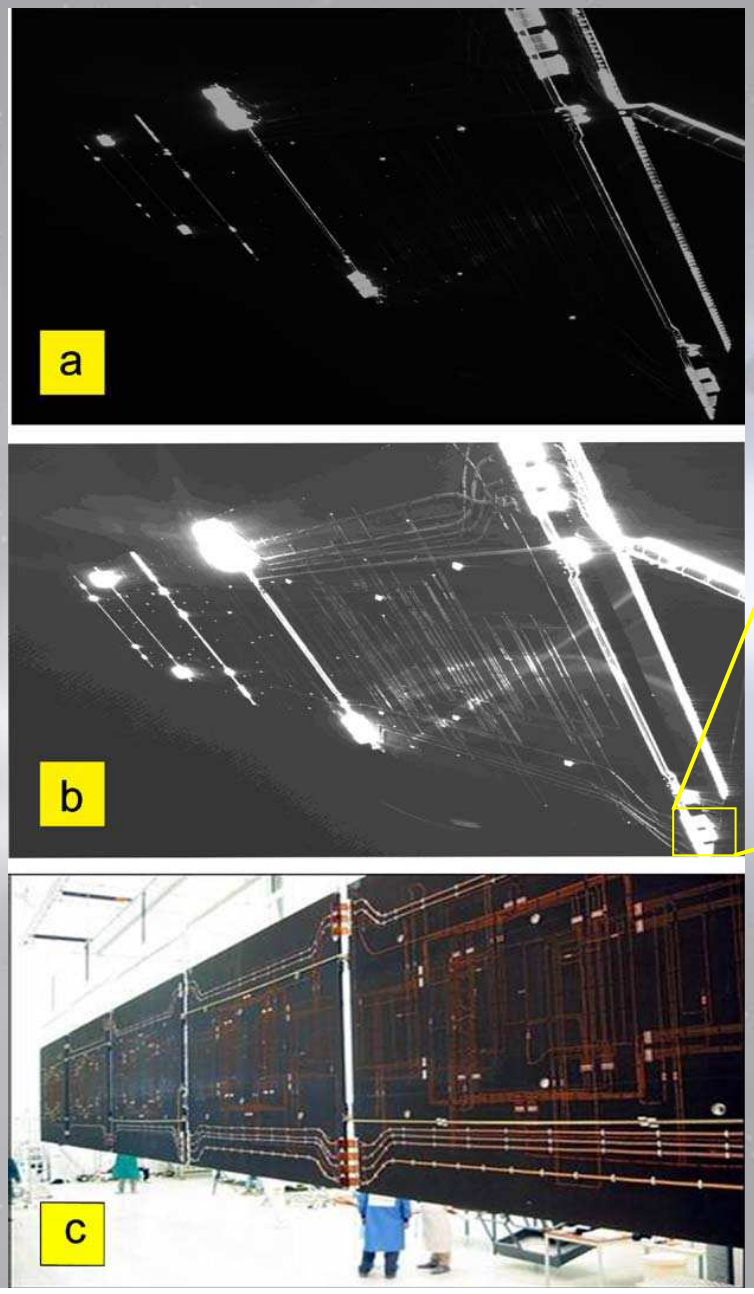


- Total 7 cameras
- 5 single, 1 stereoscopic pair
- FOV 60°
- Resolution ~1mm @1m
  ~2m at horizon
- Topography
- Albedo
- Surface features, vents, jets
- Surface changes

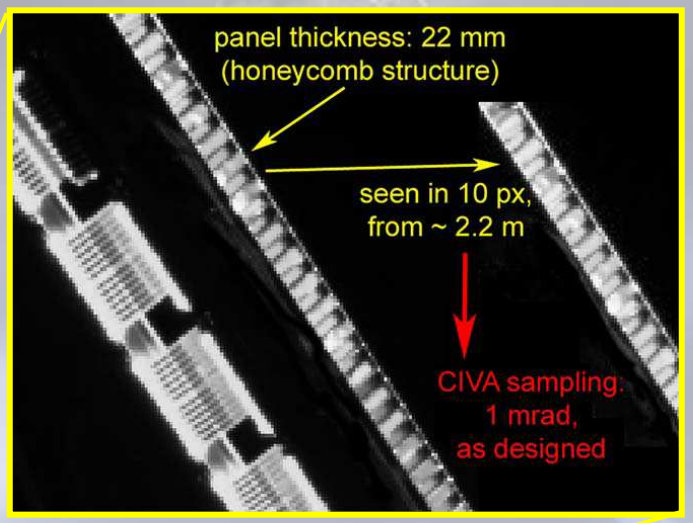


Bibring et al. 2007

CIVA-P Panoramic camera



Rosetta solar panels



CIVA at Mars

ROLIS ROsetta Lander Imaging System

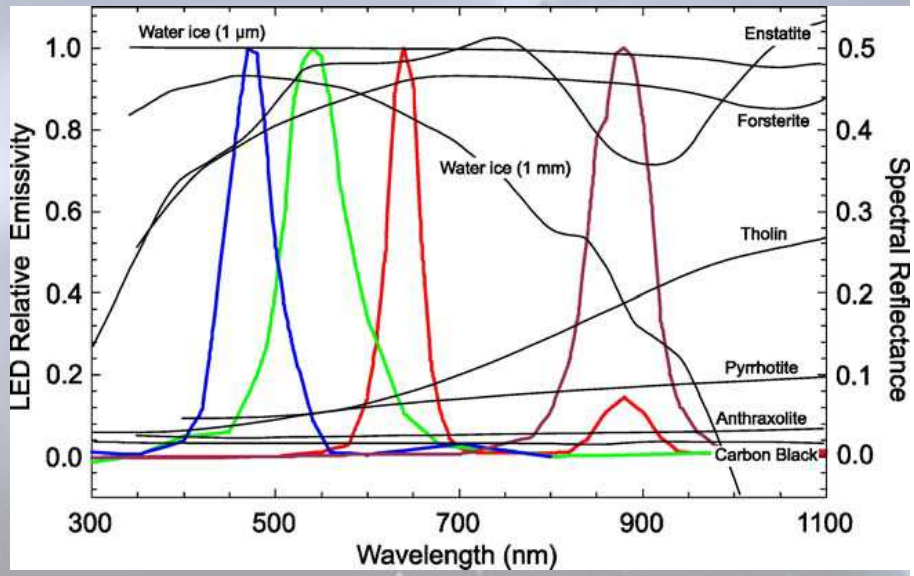
Downward looking camera

Operation during SDL

Resolution 0.3mm/pixel @30cm

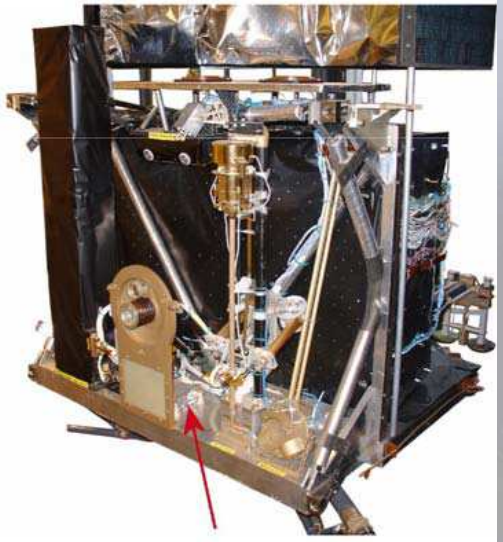
Can image drill bore hole and APXS site

Multispectral imaging
LEDs 470, 530, 640 and 870 nm



a)

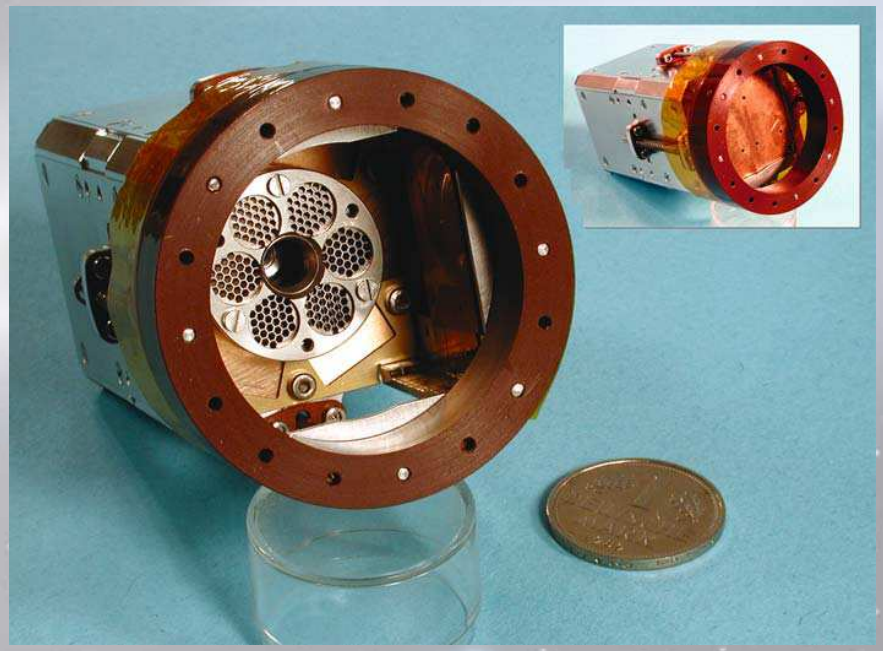
b)

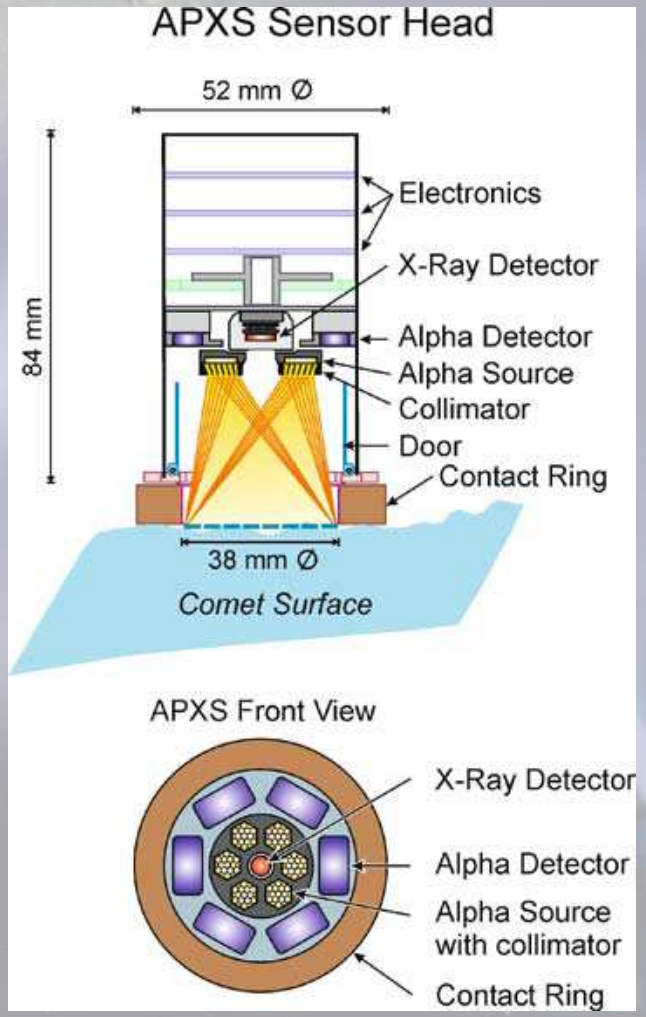


Mottola et al. 2007

APXS Alpha Particle X-ray Spectrometer

- Predecessor of MER APXS
- Curium 244 alpha source
- Elemental composition z ≥ 23
- Alpha spectrum carbon and oxygen



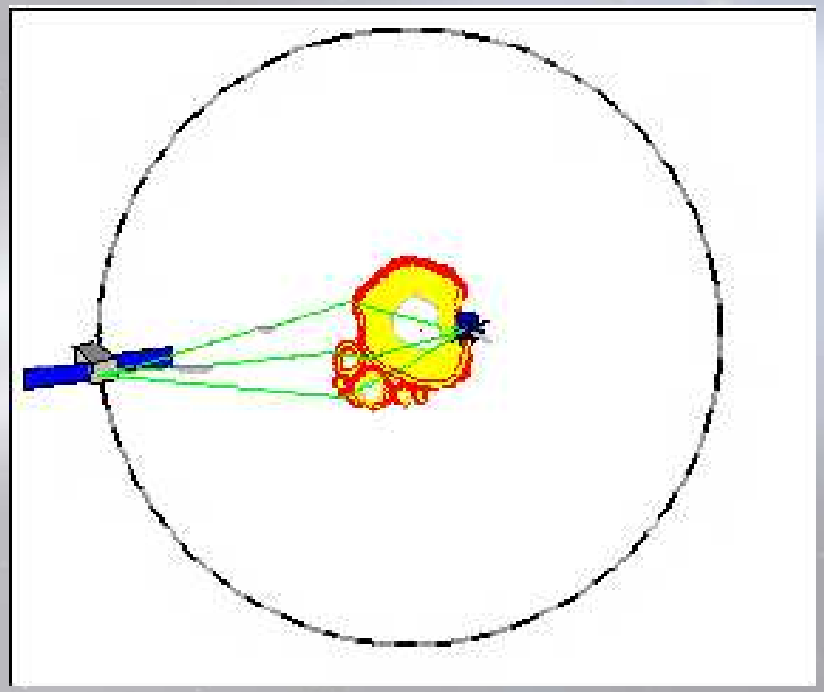


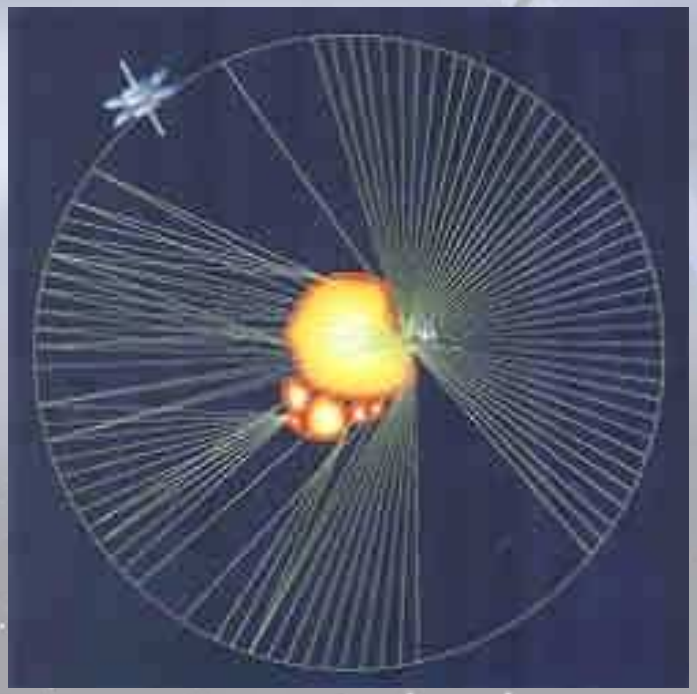
Klingelhöfer et al. 2007

CONSERT

Comet Nucleus Sounding Experiment by Radio-wave Transmission

- Internal structure of comet
- Change in velocity and amplitude of radio signal during comet orbit



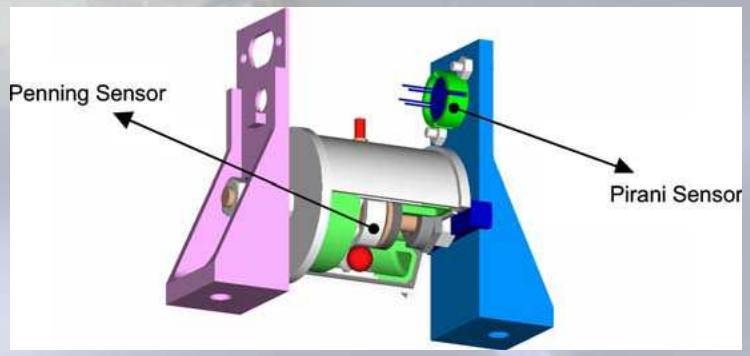


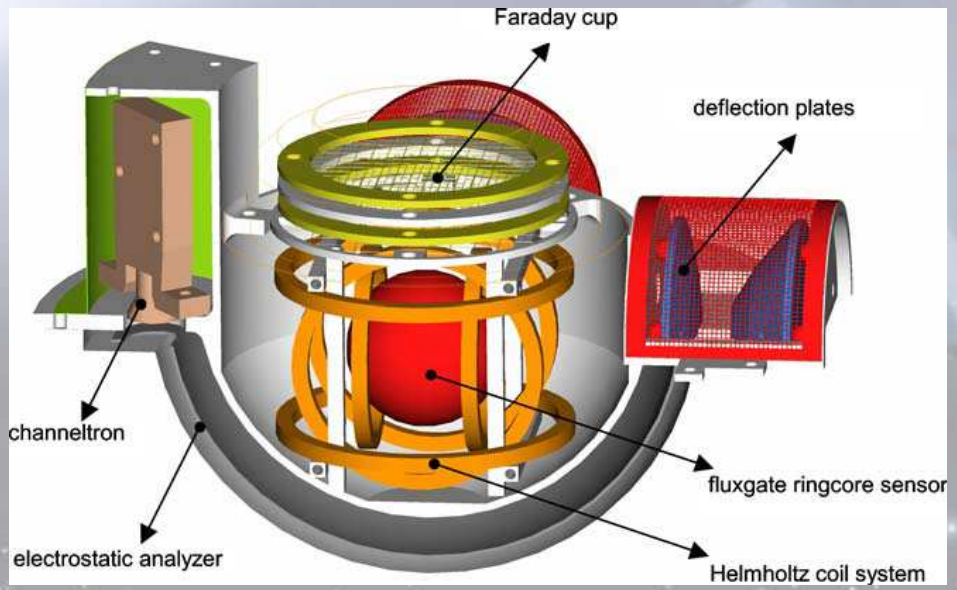
Kofman et al. 2007

ROMAP

ROsetta MAgnetmoeter and Plasma monitor

- Magnetic properties of comet
- Interaction with solar wind
- Pirani sensor 10^{-3} – 10 mbar
- Penning sensor 10^{-8} – 10^{-3} mbar
- Magnetometer
  - Range ±2000 nT
  - Resolution 10 pT
- Plasma monitor



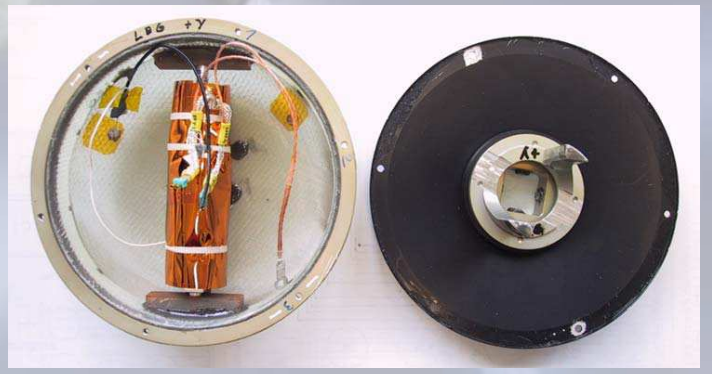


Auster et al. 2007

SESAME

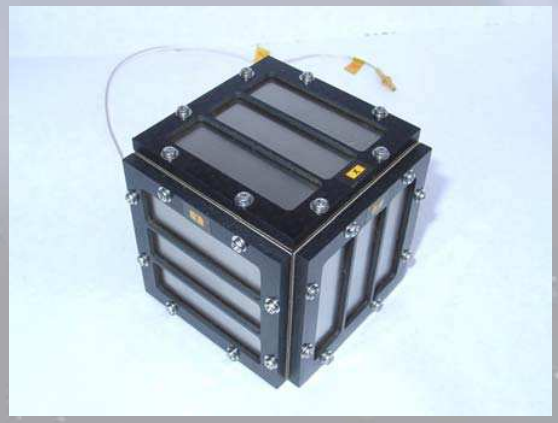
Surface Electric Sounding and Acoustic Monitoring Experiment

- CASSE Comet Acoustic Surface Sounding Experiment
  - Frequency from ~3 Hz to 3.3 kHz
  - Vertical structure



- PP Permitivity Probe
  - Water ice content

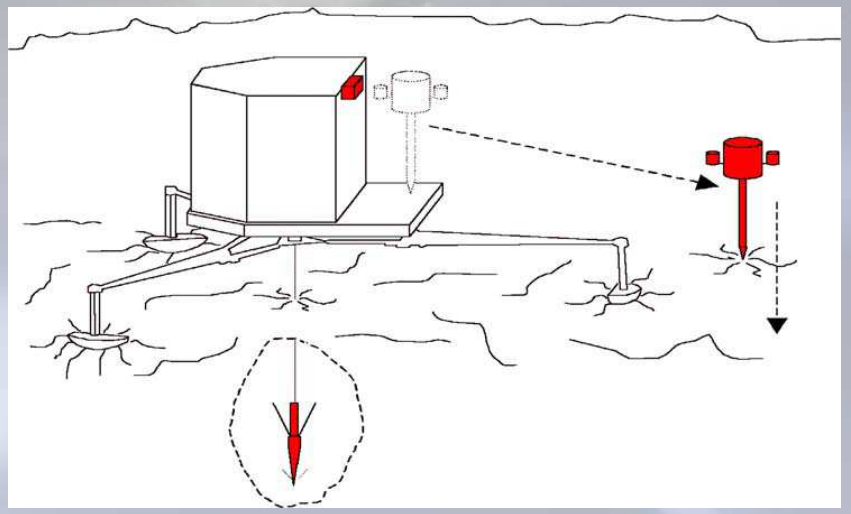
- DIM Dust Impact Monitor
  - Mechanical properties
  - Properties on impacting dust grains

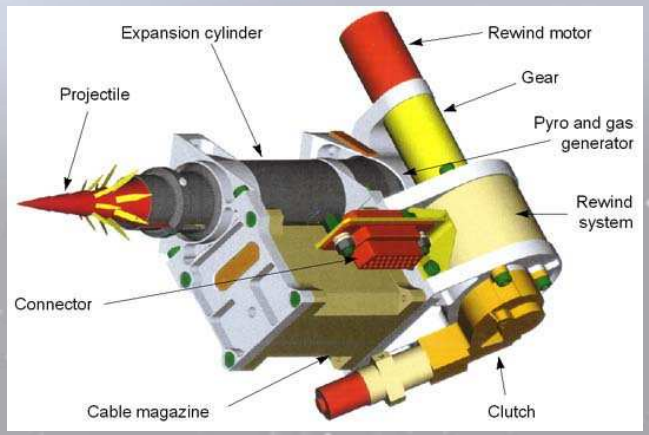


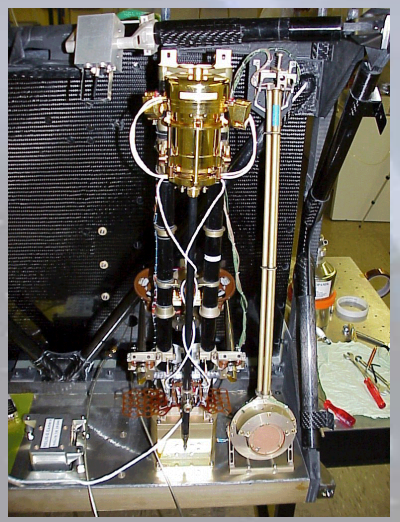
Seidensticker et al. 2007

MUPUS MUlti PUrpose Sensor package

- Physical Properties of surface layers, depth ~30cm
  - Density
  - Porosity
  - Cohesion
  - Thermal diffusivity
  - Thermal conductivity
  - Temperature
- Anchor
  - Temperature
  - Accelerometer
- MUPUS Penetrator
- Thermal Mapper



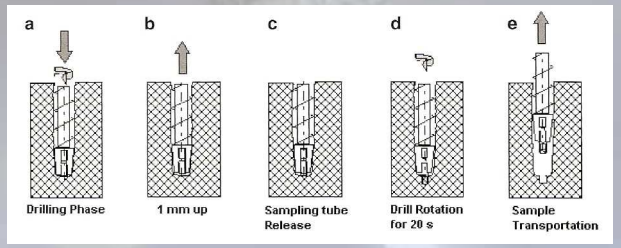


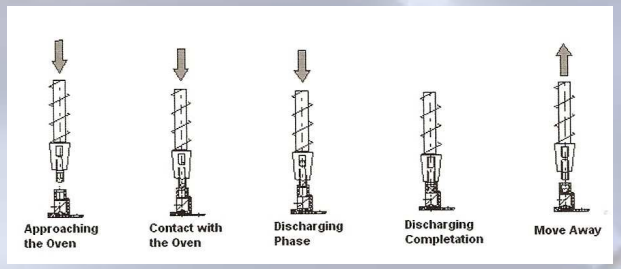


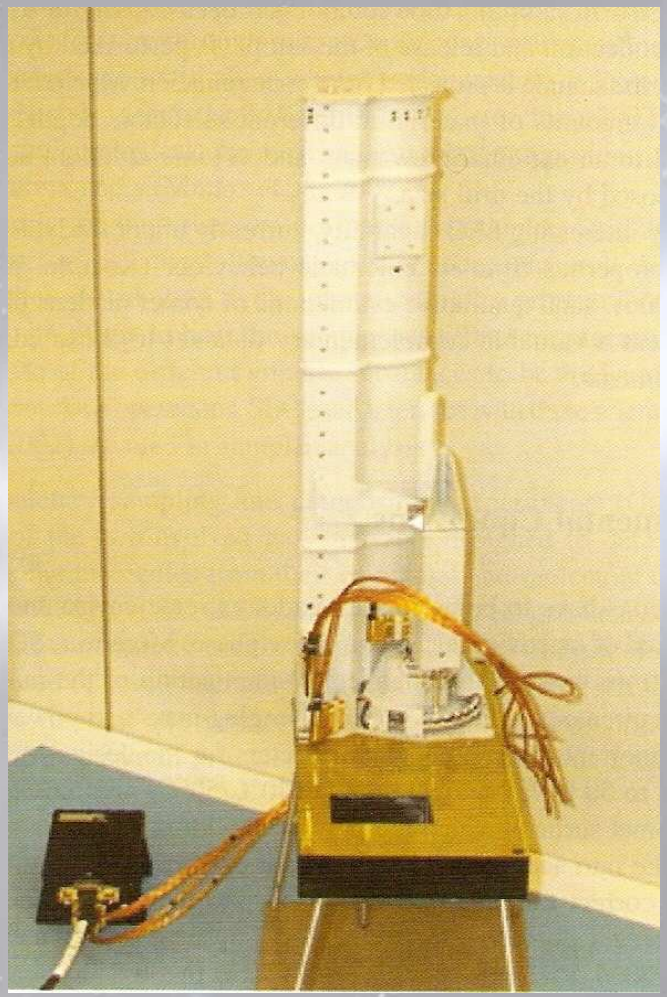
Spohn et al. 2007

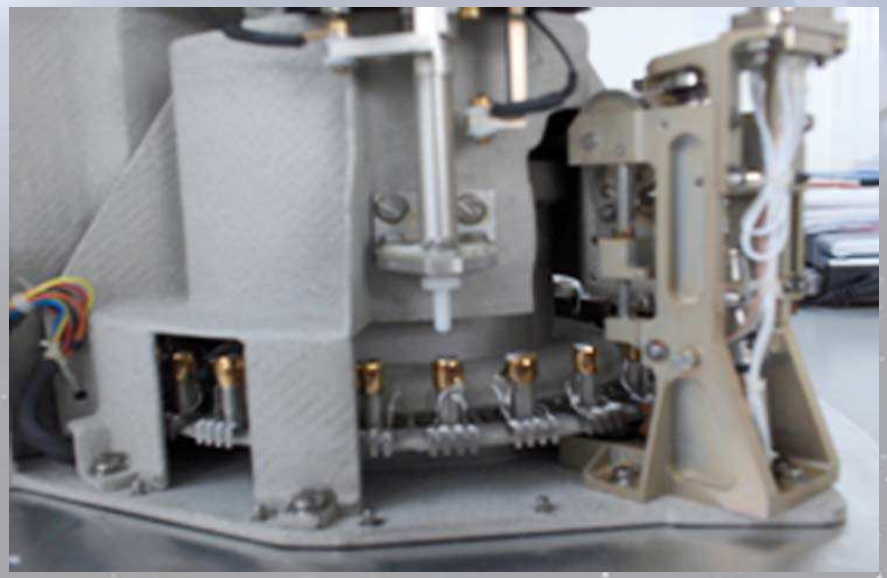
SD2 Sampler, drill & distribution system

Drill to ~ 30 cm depth
Collect sample
Deliver to oven on carousel









Finzi et al. 2007

SD2 - Sample drilling and distribution system

Collects surface and comet subsurface samples

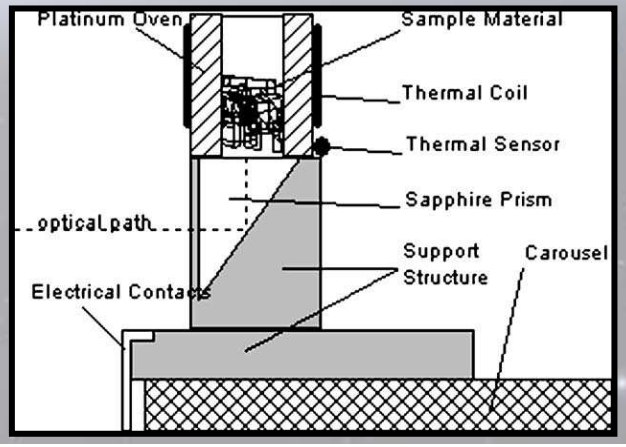
Drilling depth up to 30cm

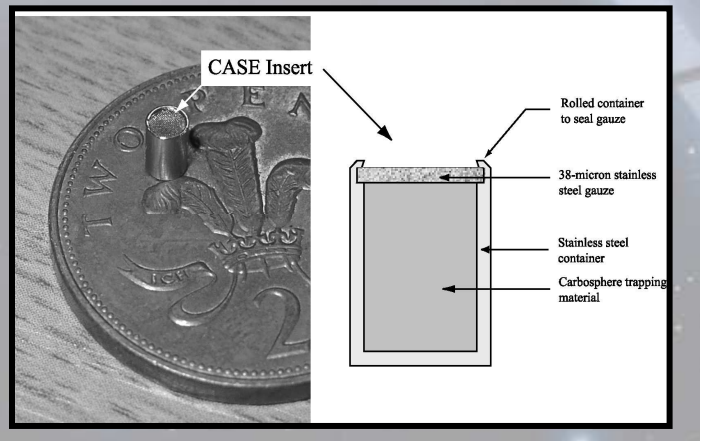
Sample size 20mm^3 ~ 3mg

Sample placed in one of 26 ovens on a carousel

16 Medium Temperature Ovens (max 180^{o}C) for CIVA microscope, COSAC and Ptolemy

10 High Temperature Ovens (max 800^{o}C) for COSAC and Ptolemy





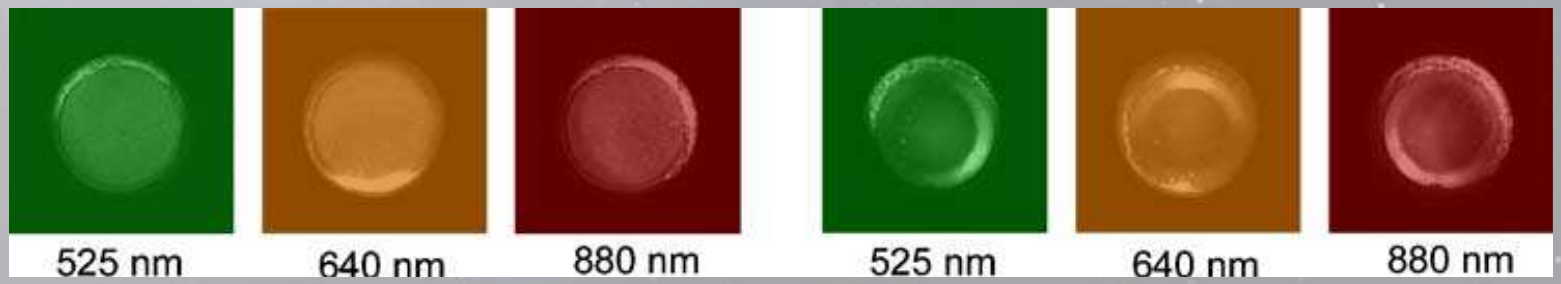
CIVA Comet Infrared and Visible Analyser

Microscope Cameras
Medium Temperature Ovens with window

- CIVA M/V - Visible
- FOV 3mm
- Resolution 7μm
- Illumination 3 LEDs
  525nm, 640nm and 880nm
- + daylight illumination

- CIVA M/I - Infrared
- FOV 3mm
- Resolution 40μm
- Spectral range 1-4μm
  3nm steps

Detection of UCAMMs?



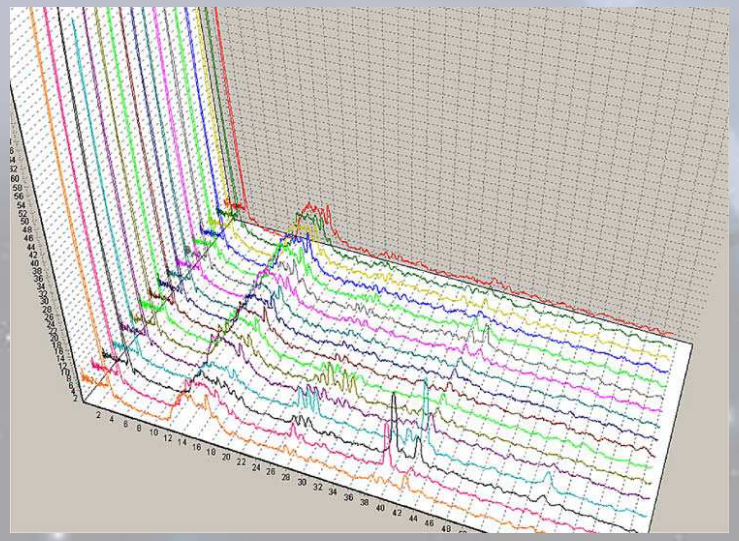
In flight calibration

Bibring et al. 2007

COSAC

COmet Sampling And Composition experiment

- GC-MS
- Pyrolysis >600℃
- Chemical processing
- 8 GC columns
  - 5 chemical composition
  - 3 Chiral
- Thermal conductivity detector
- Time Of Flight MS
  - Mass range 2-350 amu
  - Mass resolution 350



Goesmann et al. 2007

Ptolemy

Chemical processing

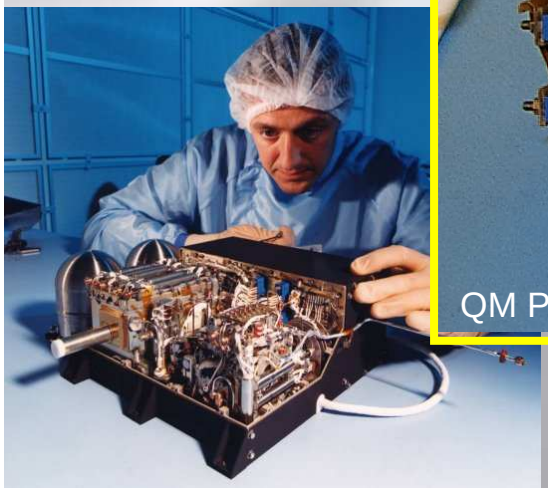
Hydrogen gas and control

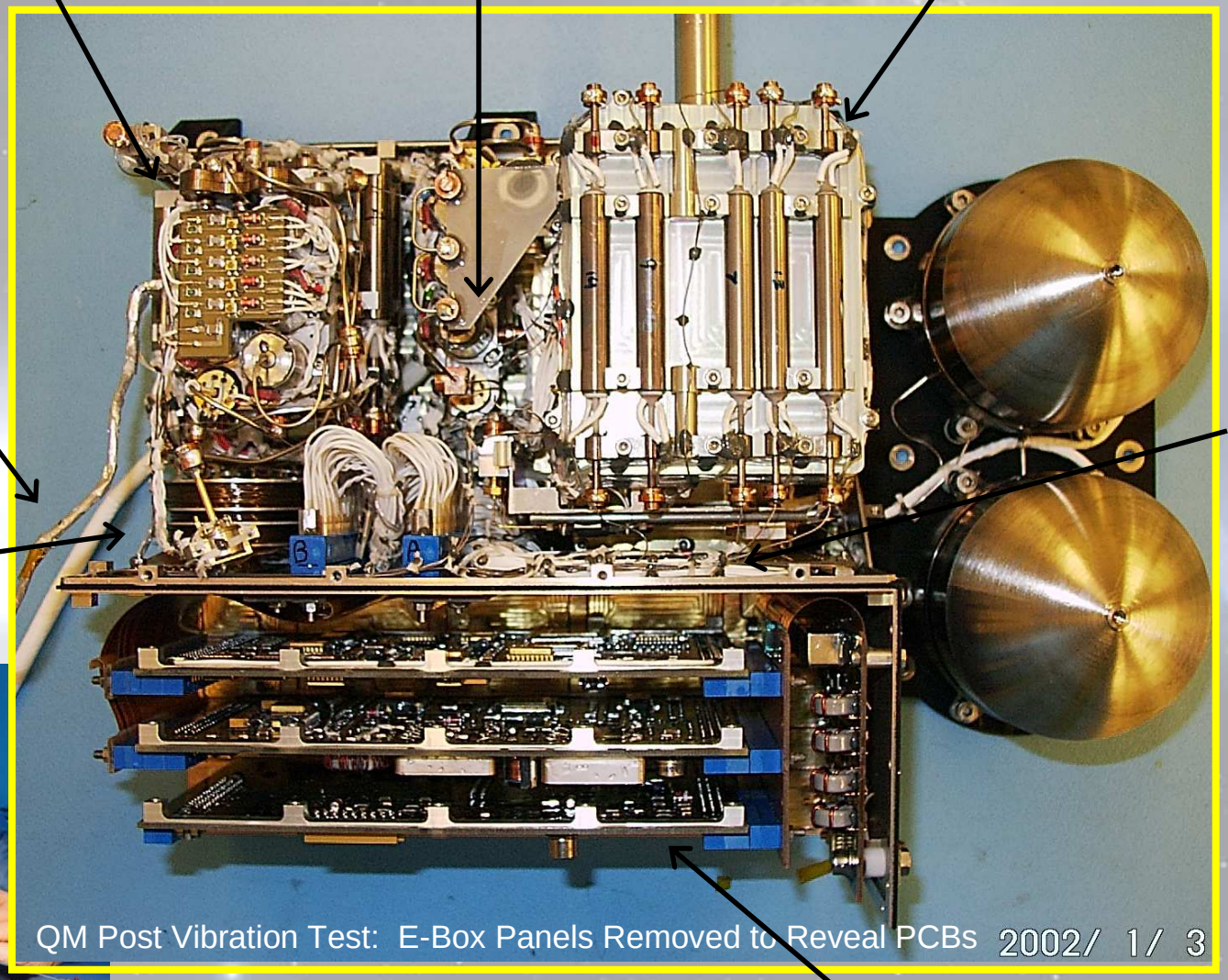
Mass Spectrometer box

Sample Inlet

Helium control

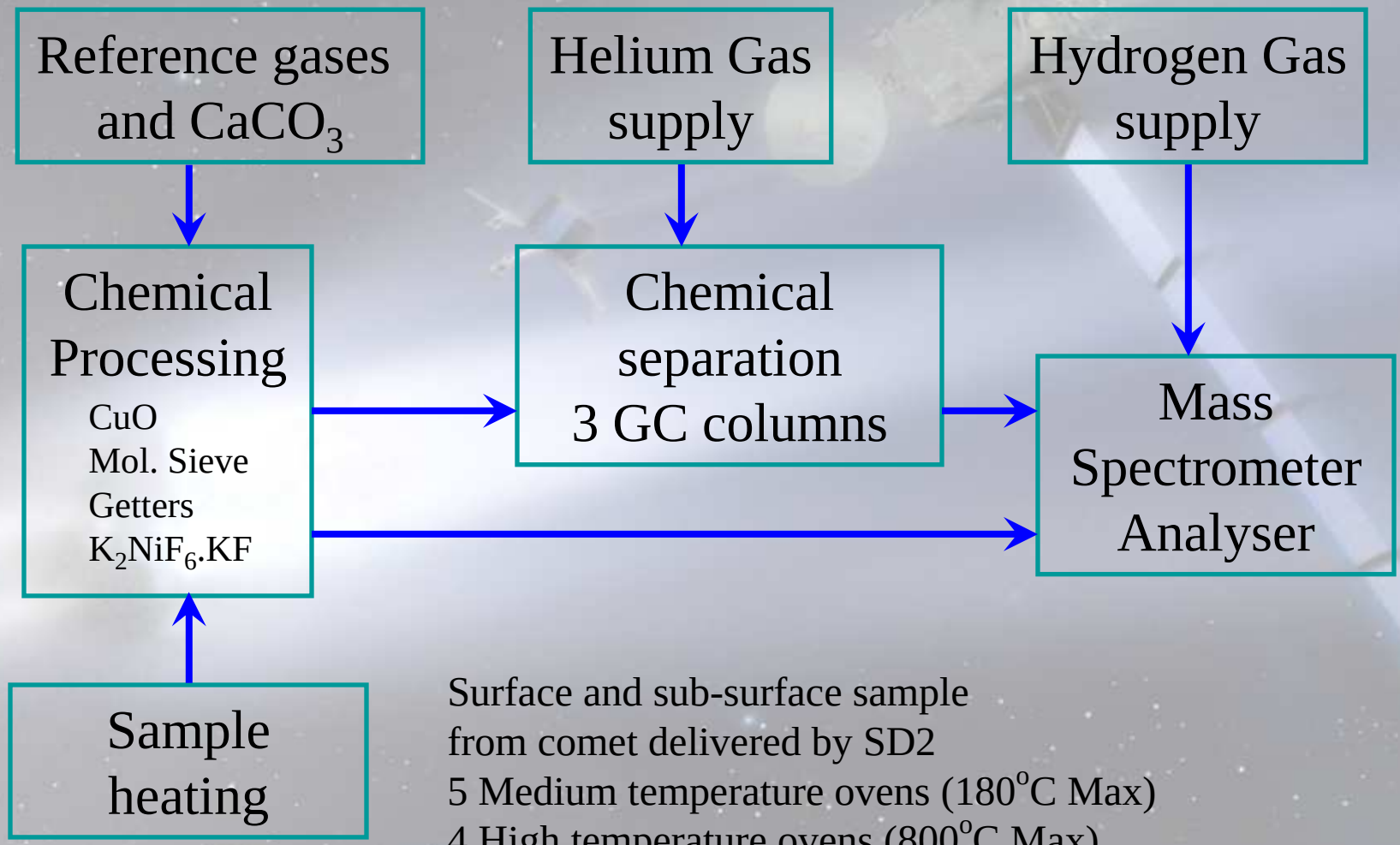
3 GC Columns





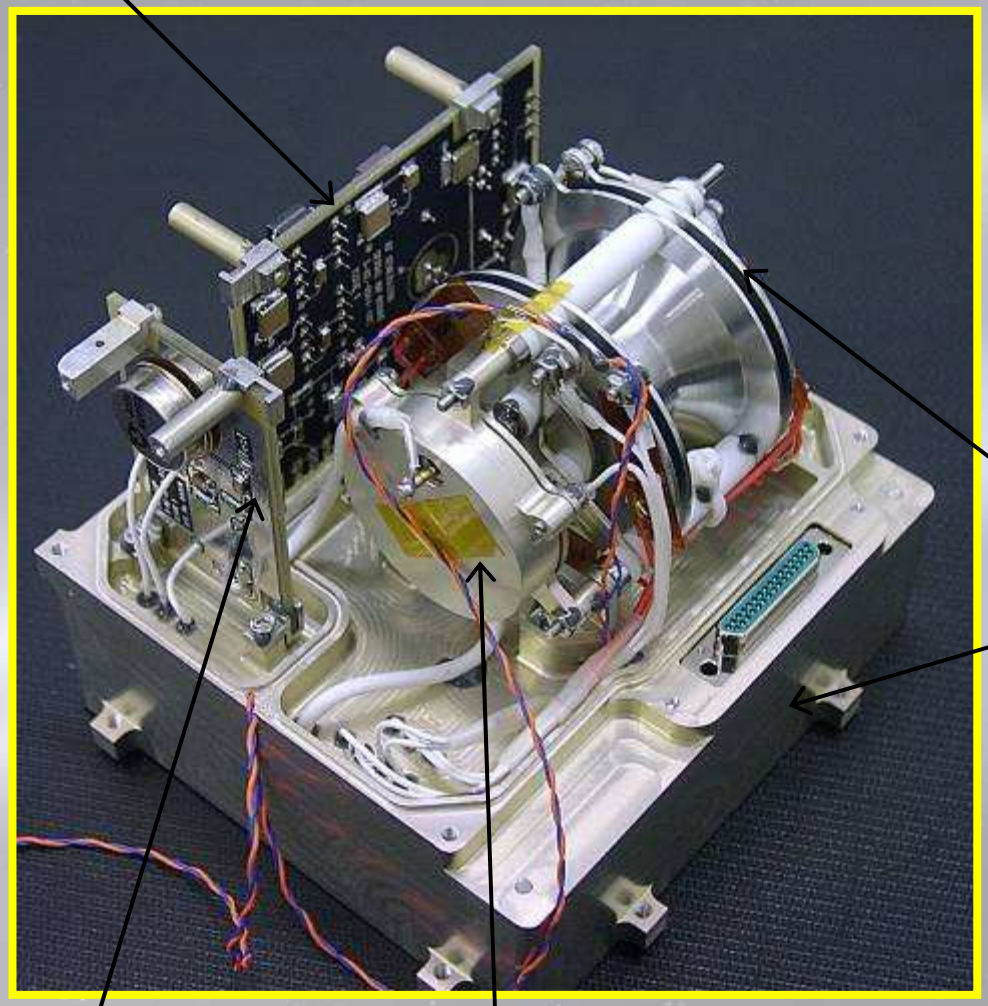
Electronics/computer

Ptolemy - System Diagram



Surface and sub-surface sample
from comet delivered by SD2
5 Medium temperature ovens (180°C Max)
4 High temperature ovens (800°C Max)
1 of which contains coma trapping material

Ptolemy Mass Spectrometer - Ion Trap



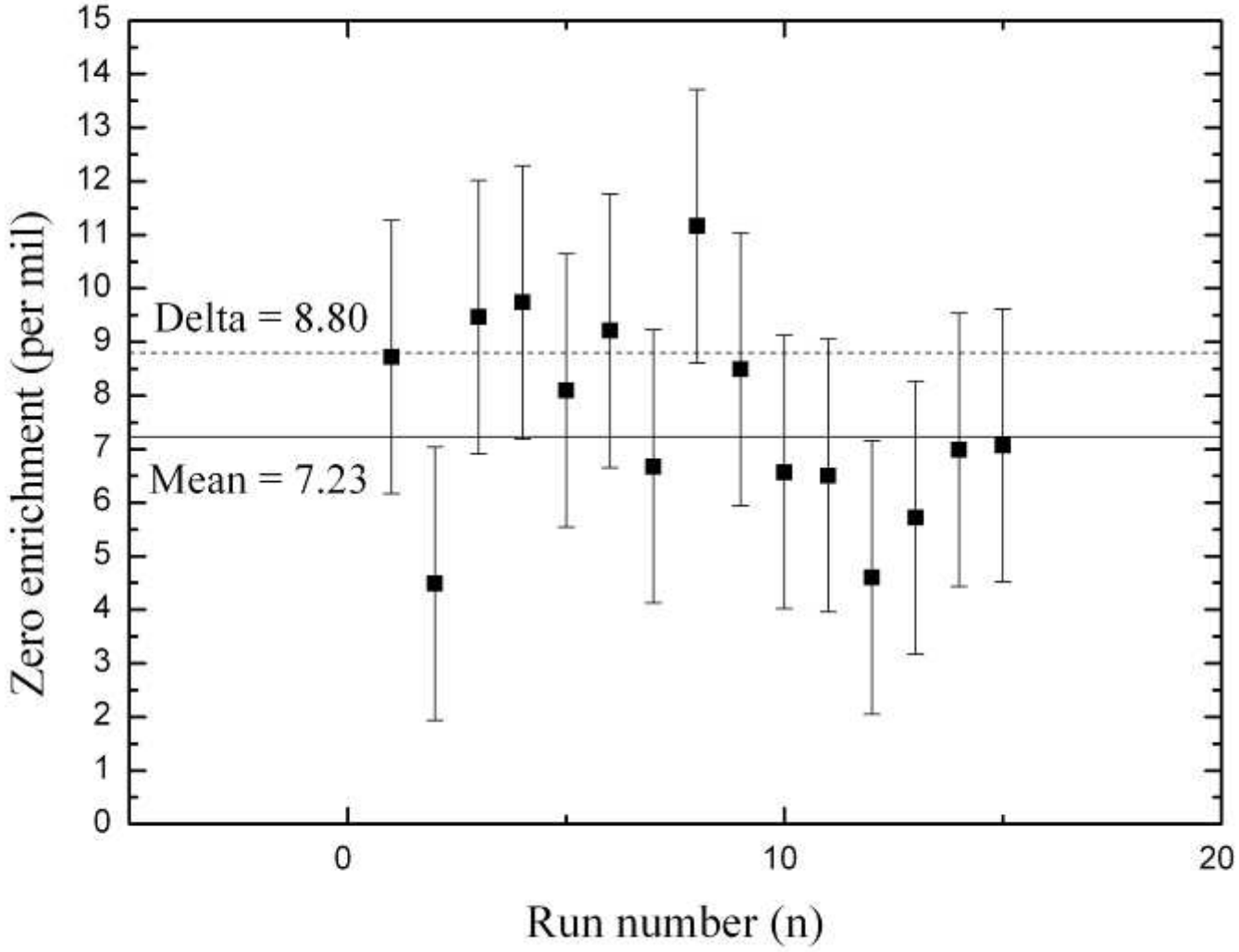
Compact mass spectrometer
No permanent magnets
Operate at 10^{-3} mbar

Mass range 10 to 150 amu
Resolving Power better than unit

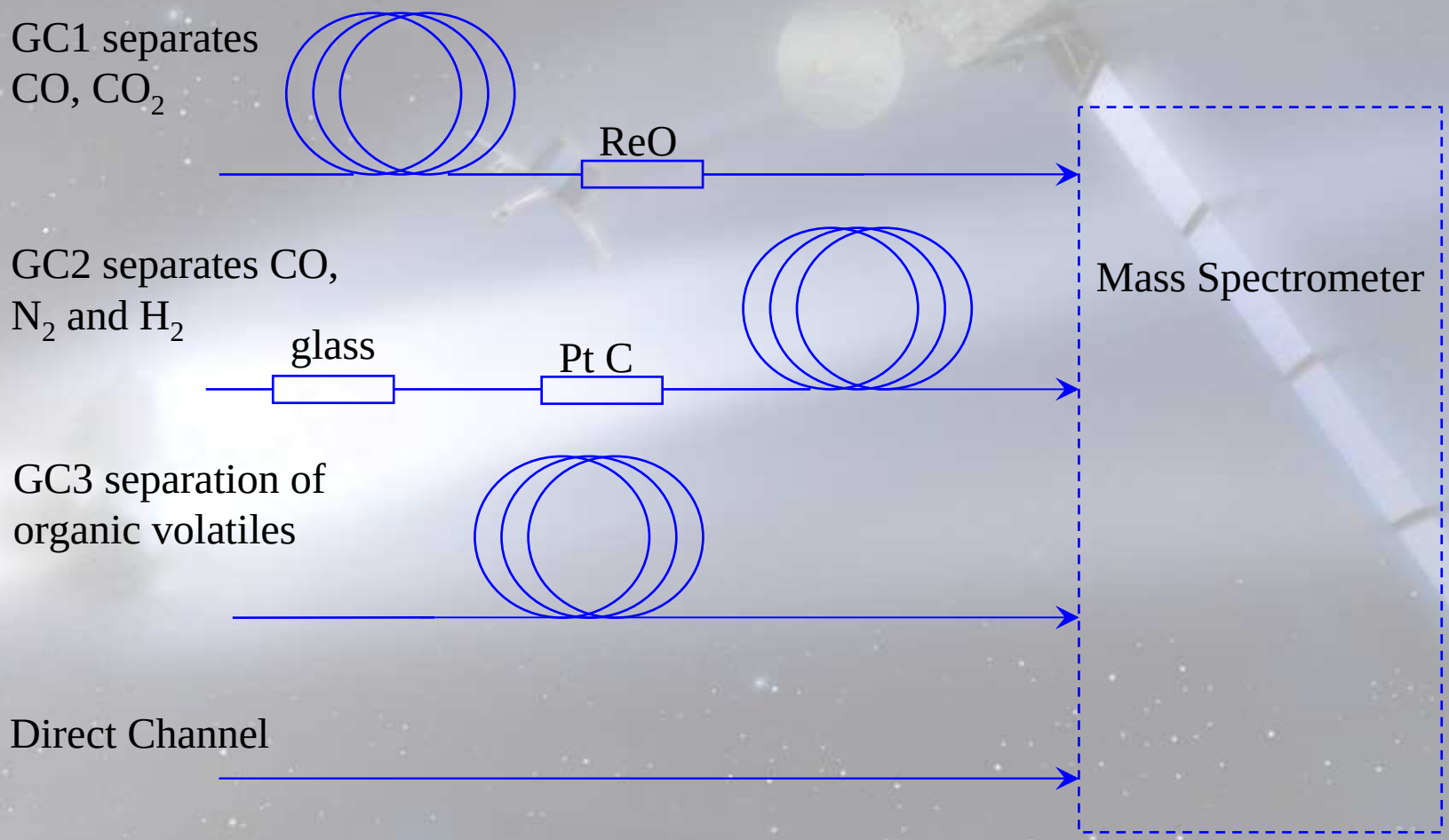
Volume 10 x 9 x 9 cm
Electrode mass 50g
Overall mass < 500g
Power ~ 1W

Measurement of ^{13}C isotope ratios

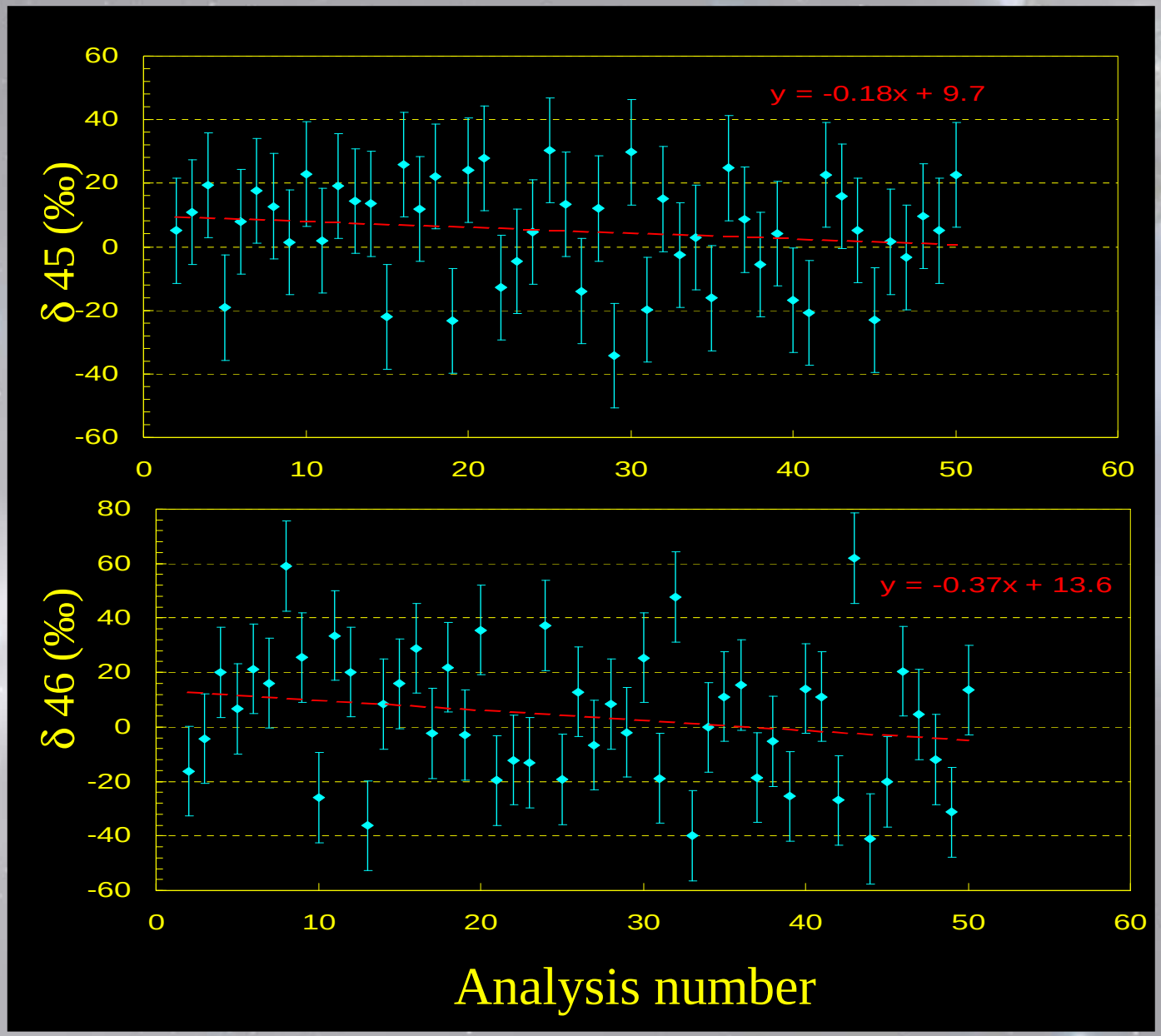
Comparison of a sample gas 8.8 per mil heavier than a reference gas



GC Columns


GC1 separates
CO, CO_2
ReO
GC2 separates CO,
N_2 and H_2
glass
Pt C
GC3 separation of
organic volatiles
Direct Channel
Mass Spectrometer

Zero Enrichment analysis of CO_2



Sample size 20 nmol
Analysis time 5
minutes per sample

δ45
1 σ error 17 ‰
average 5.0 ‰

δ46
1 σ error 25 ‰
average 4.0 ‰

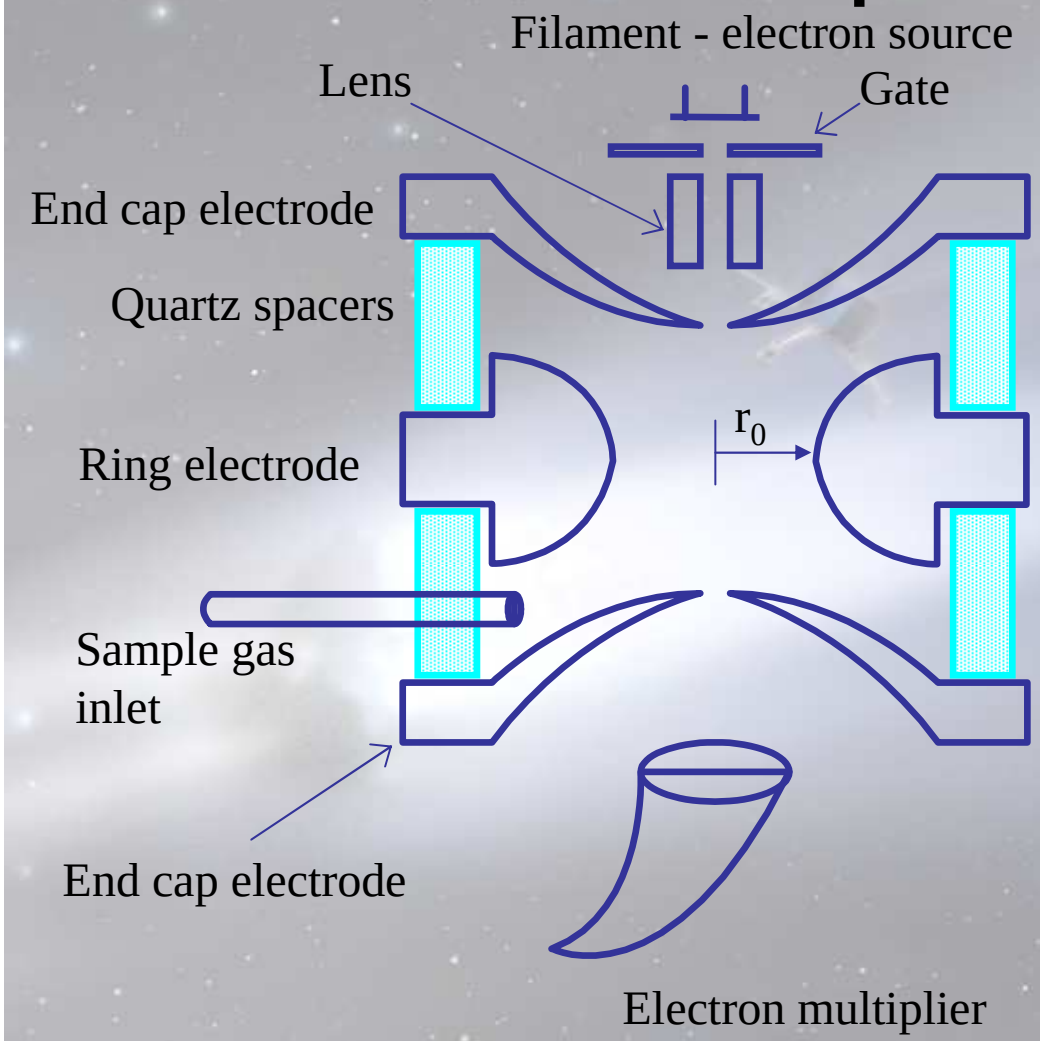
Payload Summary

Instrument	Investigations	Mass (kg)	
• CIVA	Cameras, microscope	3.4	☑
• ROLIS	Descent camera	1.4	
• APXS	Elemental Composition	1.3	
• CONSERT	Internal Structure	1.8	
• ROMAP	Magnetic and Plasma	0.7	☑
• SESAME	Structure, dust impact	1.8	☑
• MUPUS	Physical properties	2.2	
• SD2	Sample acquisition, structure	4.7	
• COSAC	Molecular composition	4.9	☑
• Ptolemy	Isotopic composition	4.5	☑
Total		26.7	

Science before SDL ☑

Additional Slides

Mass Spectrometer

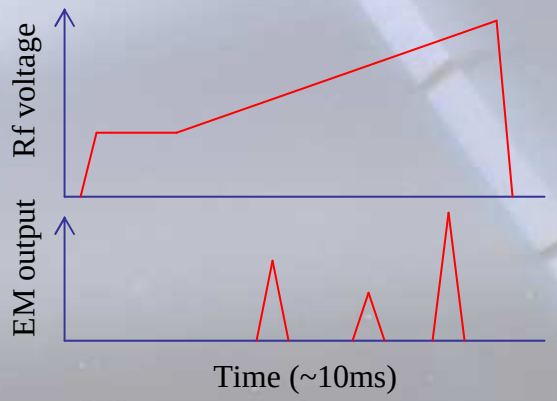


Advantages:

- Compact design
- No magnets
- Operate at 10^{-3} mbar

$$V_{ej} = \frac{m\, r_0^2\, \Omega^2}{4e}$$

Scan function:

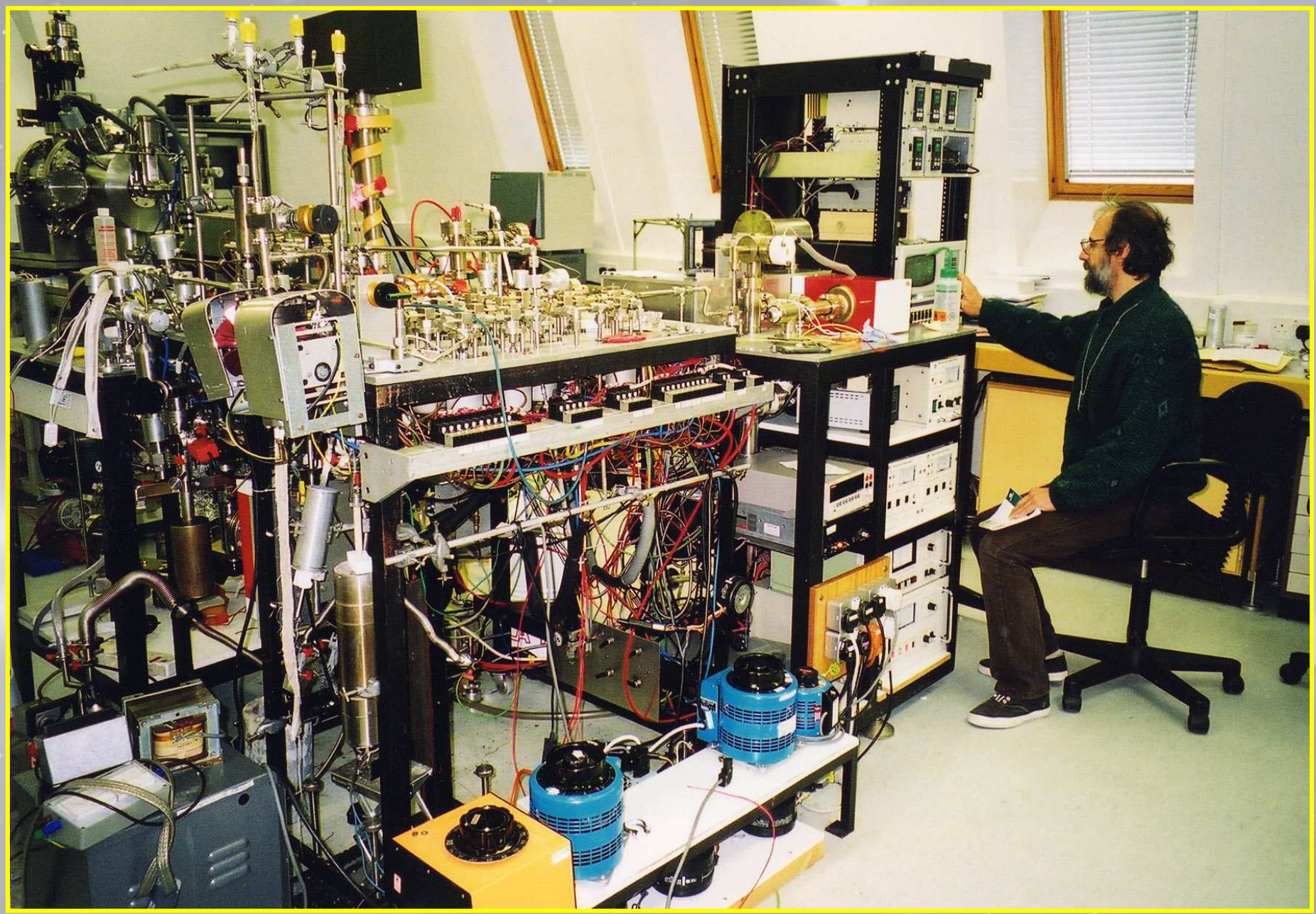


R_o = 8mm

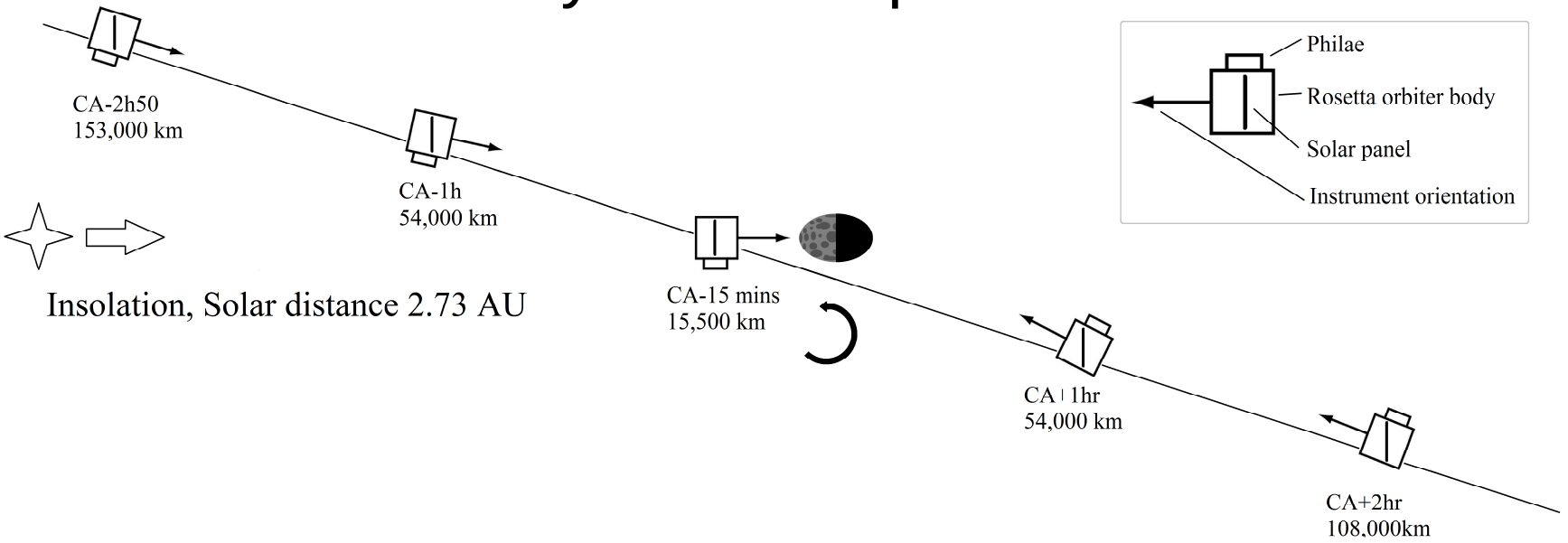
Frequency ~0.55MHz

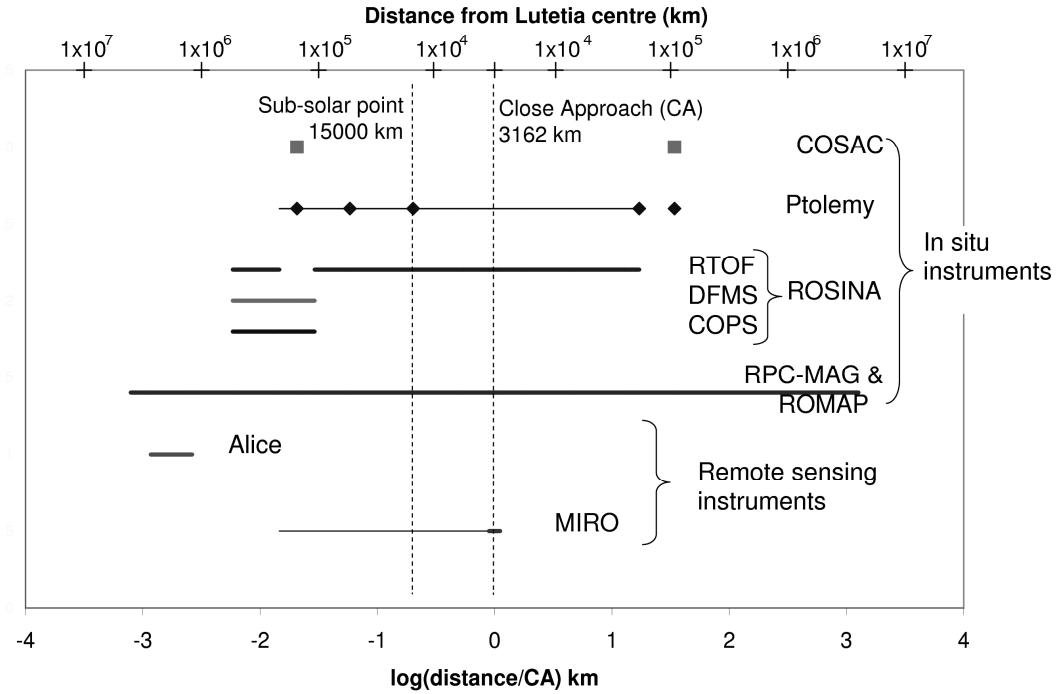
1.8 V/amu

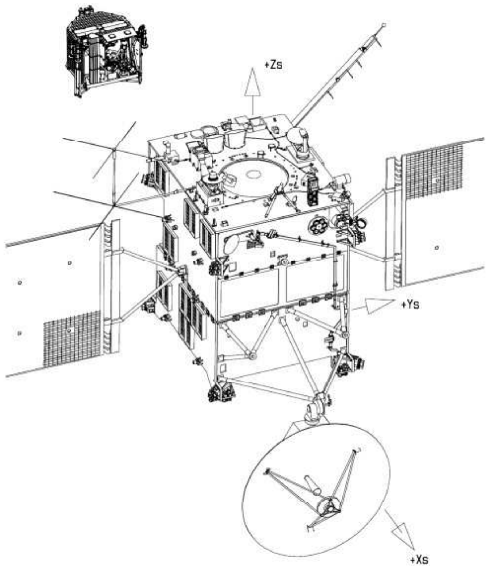
Mass Spectrometer – Open University

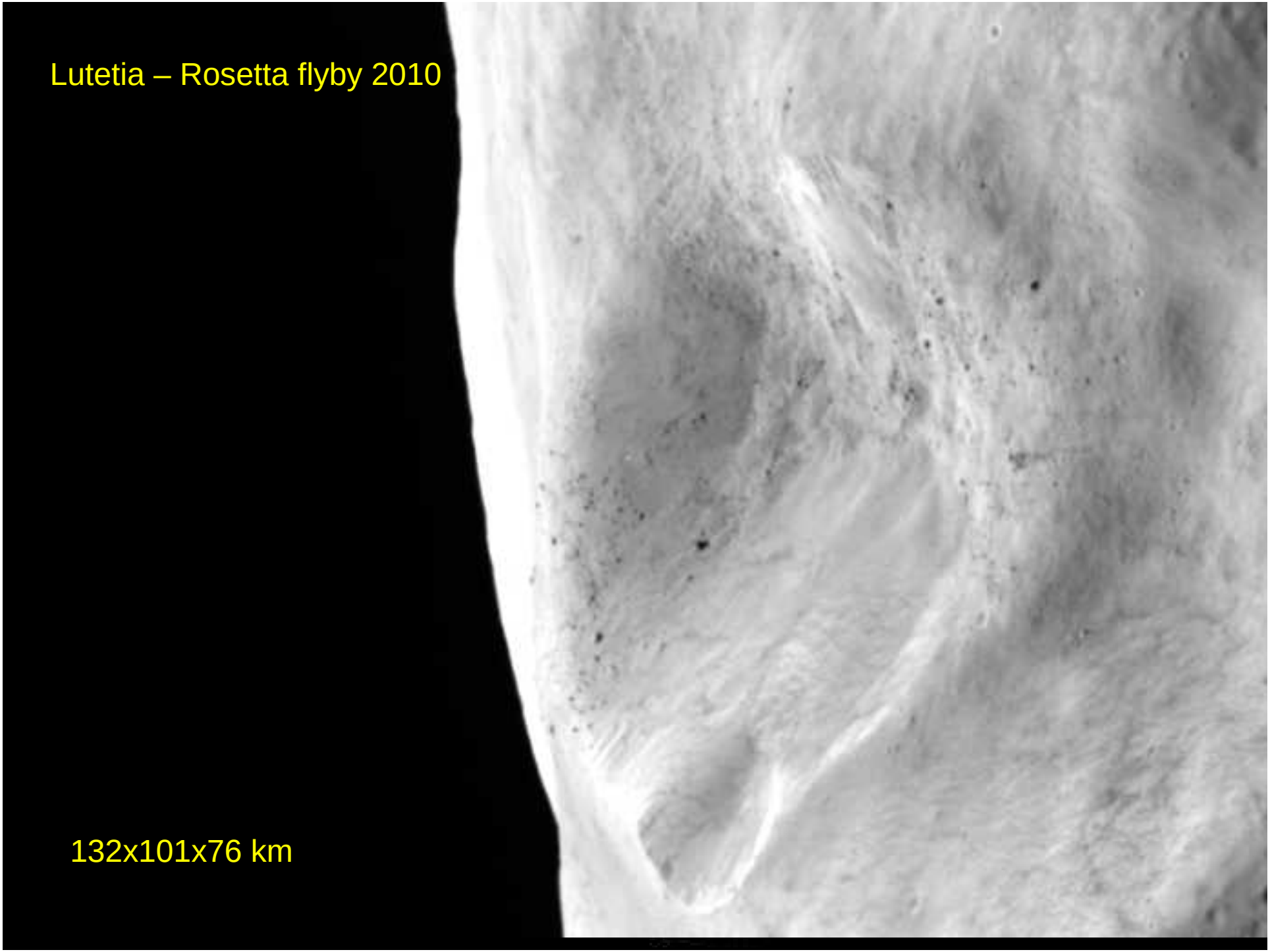


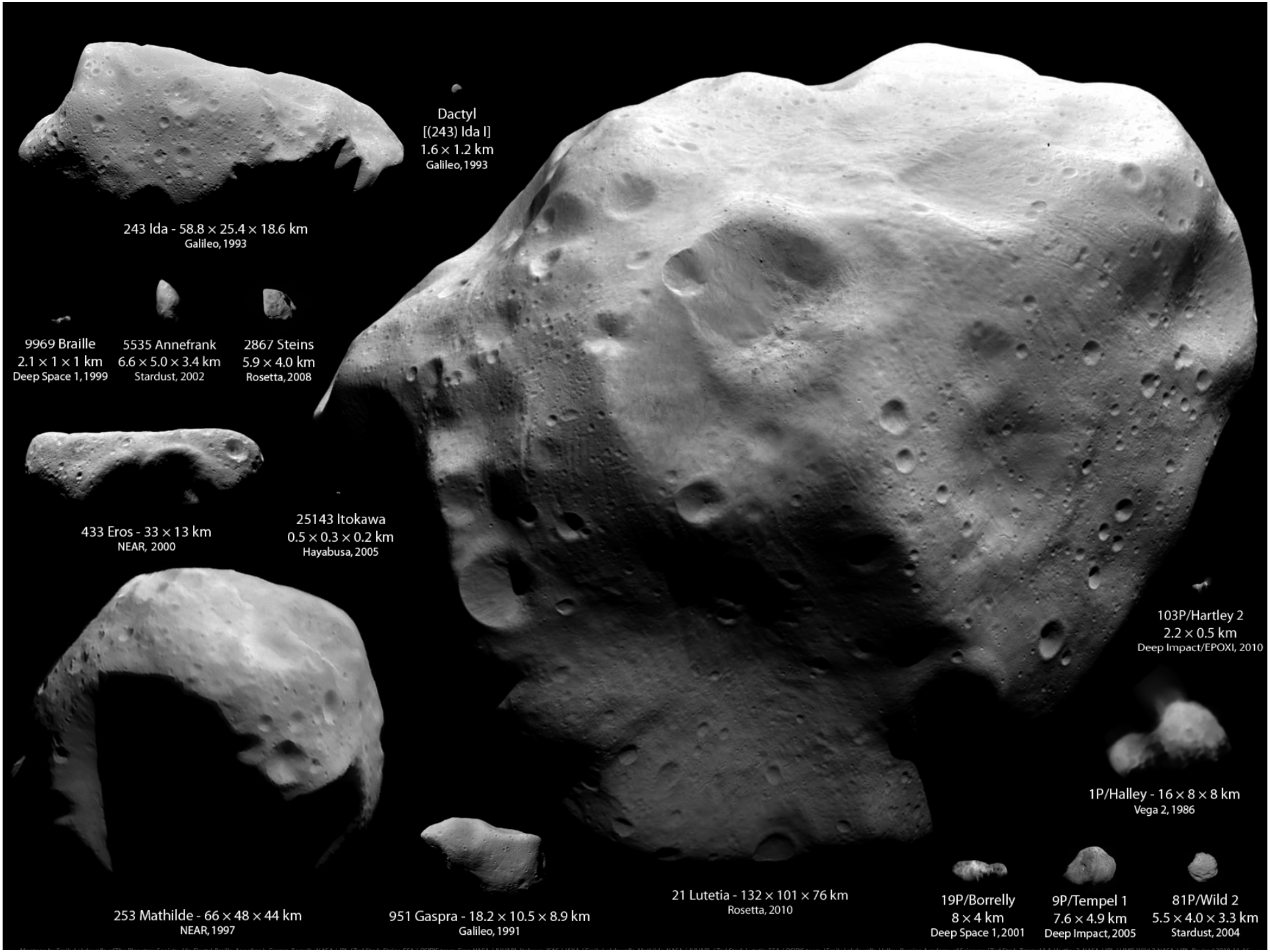
Ptolemy Lutetia Operations

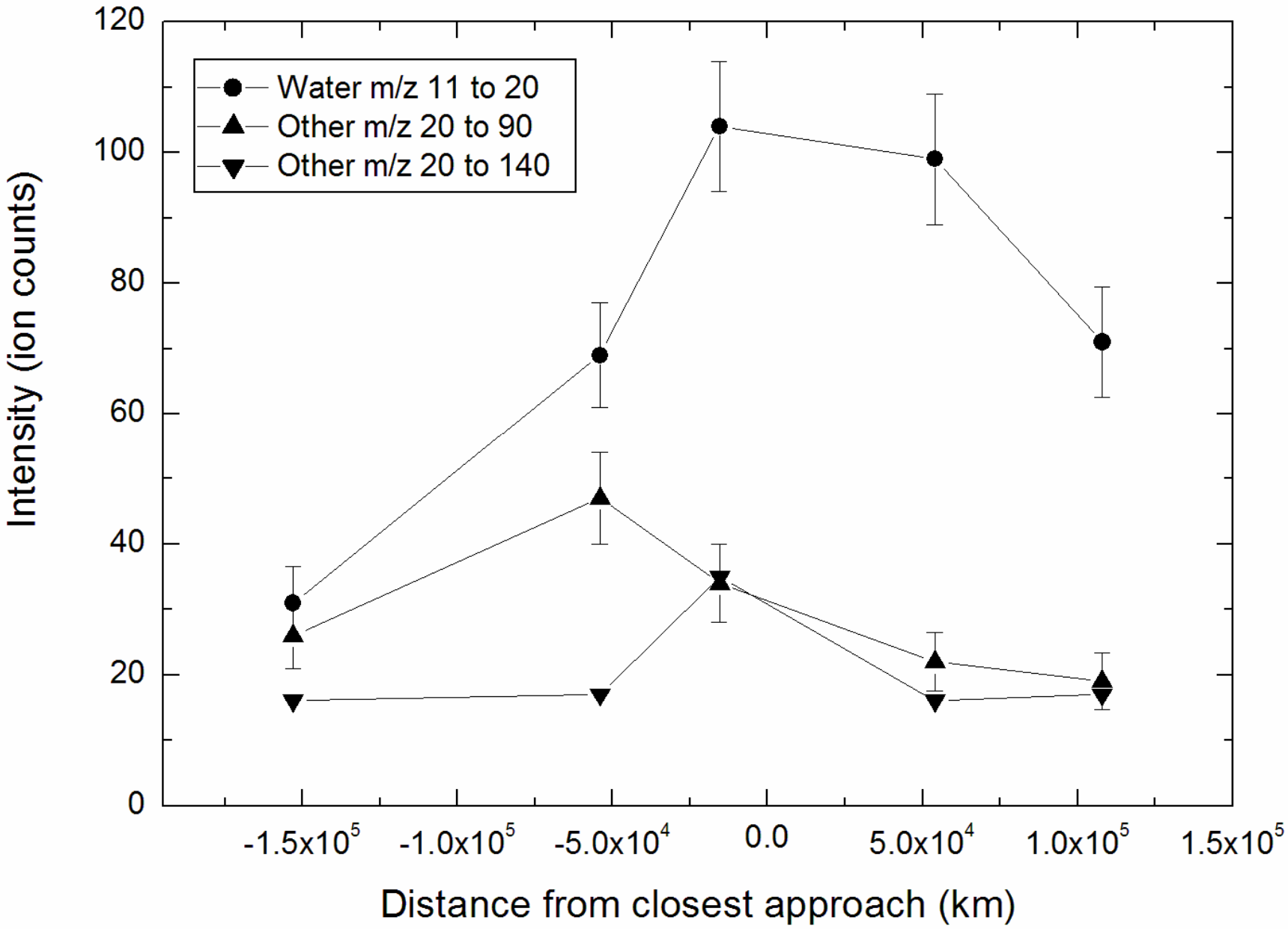




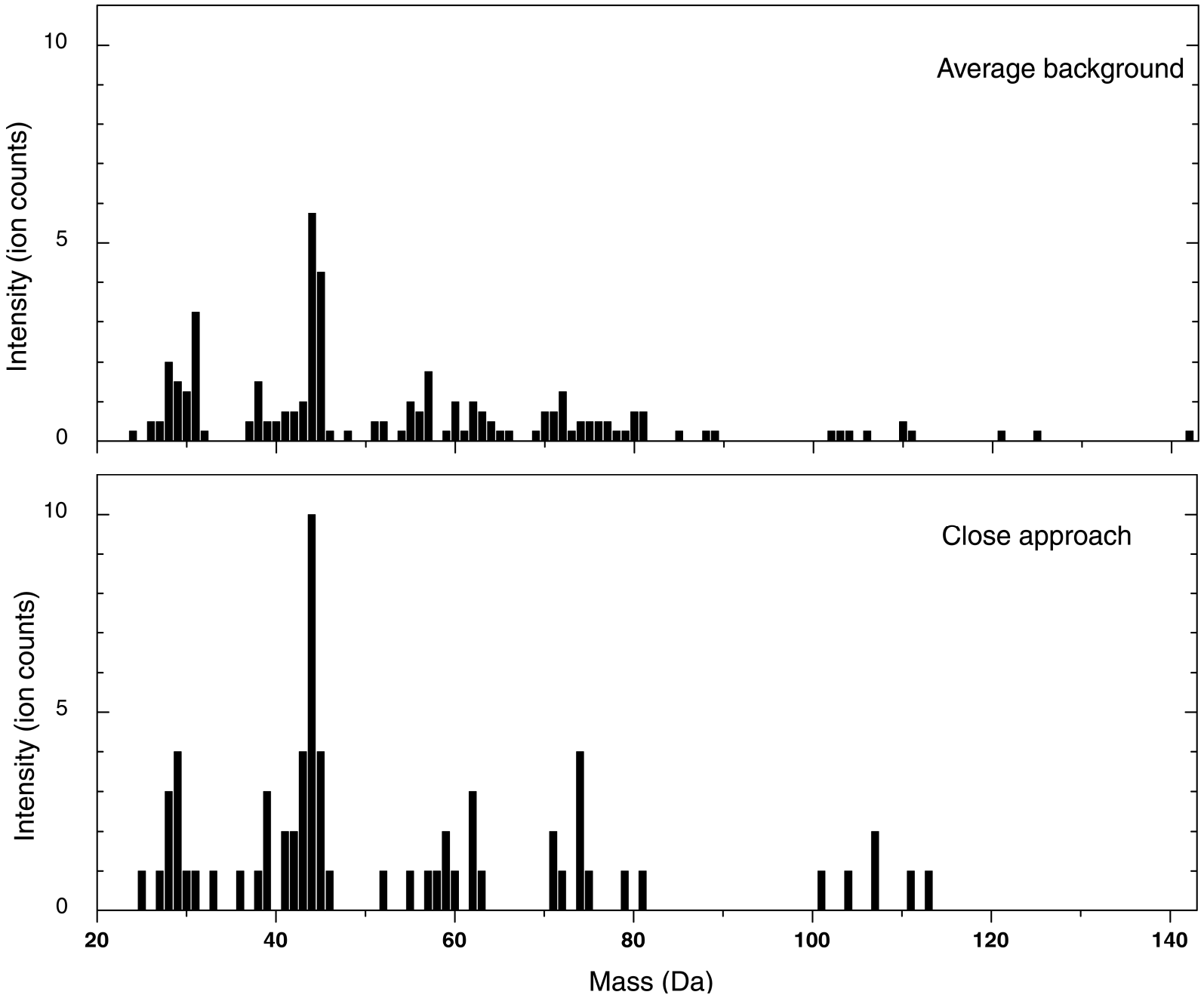


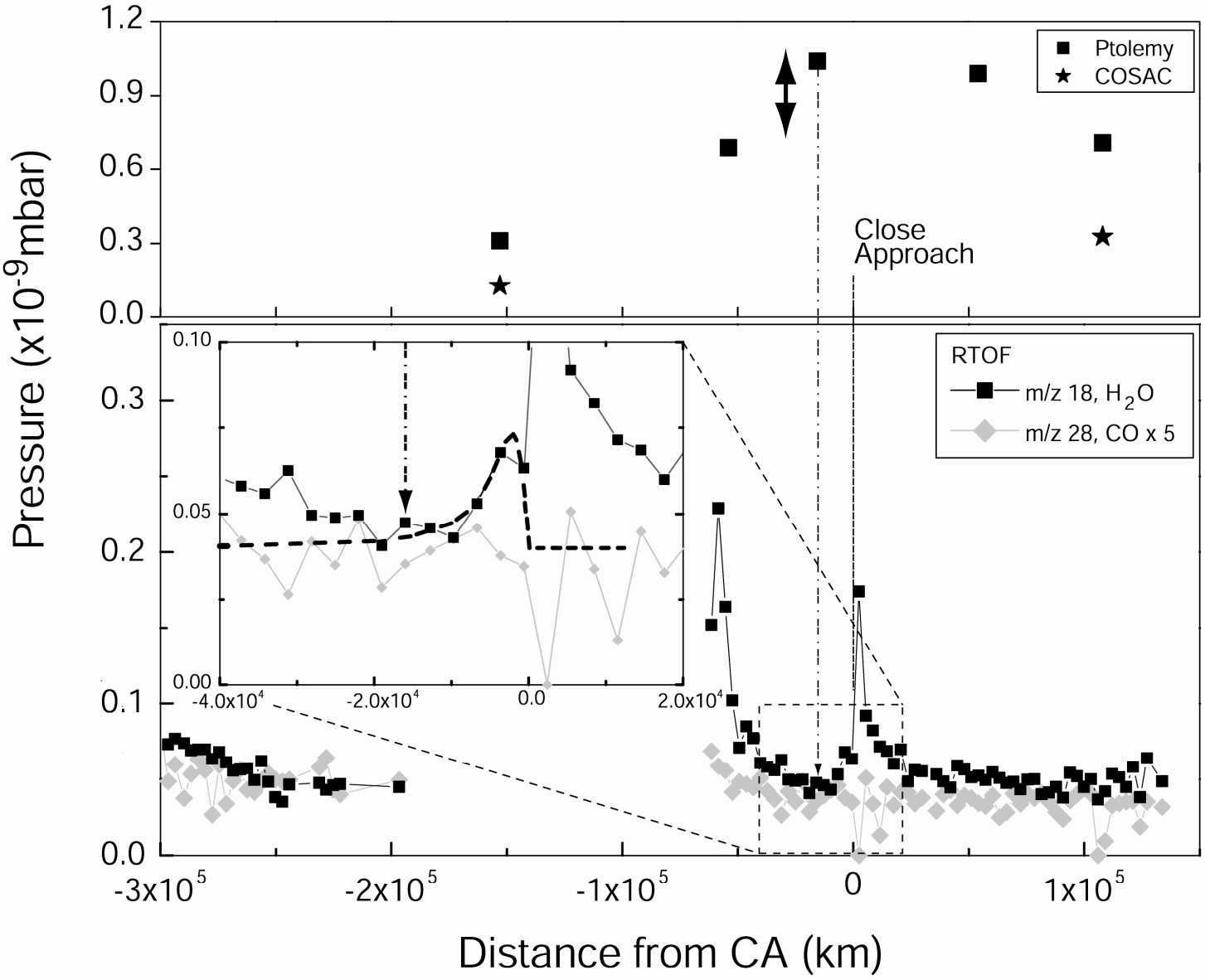

Lutetia – Rosetta flyby 2010
132x101x76 km


Dactyl
[(243) Ida I]
1.6 × 1.2 km
Galileo, 1993
243 Ida - 58.8 × 25.4 × 18.6 km
Galileo, 1993
9969 Braille
2.1 × 1 × 1 km
Deep Space 1, 1999
5535 Annefrank
6.6 × 5.0 × 3.4 km
Stardust, 2002
2867 Steins
5.9 × 4.0 km
Rosetta, 2008
433 Eros - 33 × 13 km
NEAR, 2000
25143 Itokawa
0.5 × 0.3 × 0.2 km
Hayabusa, 2005
103P/Hartley 2
2.2 × 0.5 km
Deep Impact/EPOXI, 2010
1P/Halley - 16 × 8 × 8 km
Vega 2, 1986
253 Mathilde - 66 × 48 × 44 km
NEAR, 1997
951 Gaspra - 18.2 × 10.5 × 8.9 km
Galileo, 1991
21 Lutetia - 132 × 101 × 76 km
Rosetta, 2010
19P/Borrelly
8 × 4 km
Deep Space 1, 2001
9P/Tempel 1
7.6 × 4.9 km
Deep Impact, 2005
81P/Wild 2
5.5 × 4.0 × 3.3 km
Stardust, 2004


Water m/z 11 to 20
Other m/z 20 to 90
Other m/z 20 to 140
Intensity (ion counts)
120
100
80
60
40
20
0
-1.5x10^5
-1.0x10^5
-5.0x10^4
0.0
5.0x10^4
1.0x10^5
1.5x10^5
Distance from closest approach (km)

Ptolemy Mass Spectra




Pressure (x10-9mbar)
1.2
0.9
0.6
0.3
0.0
Ptolemy
COSAC
Close
Approach
RTOF
m/z 18, H2O
m/z 28, CO x 5
0.10
0.05
0.00
-4.0x10^4
-2.0x10^4
0.0
2.0x10^4
0.3
0.2
0.1
0.0
-3x10^5
-2x10^5
-1x10^5
0
1x10^5
Distance from CA (km)